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Past Annual Meetings

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1987	Durham (NH), USA	M. Teghtsoonian and R. Teghtsoonian
1988	Stirling, UK	H. Ross, R. MacDonald, C. A. Possamaï, R. Teghtsoonian, M. Treisman, and R. Warren
1989	Cassis, France	A. M. Bonnet, G. Canèvet, C. A. Possamaï, and B. Scharf
1990	Würzburg, Germany	F. Müller
1991	Durham (NC), USA	G. R. Lockhead
1992	Stockholm, Sweden	G. Borg, Å. Hellström, and G. Neely
1993	Mallorca, Spain	A. Garriga-Trillo, P. R. Miñón, C. García-Gallego, P. Lubin, J. M. Merino, M. J. Rubio-Gómez, and A. Villarino
1994	Vancouver, Canada	L. M. Ward
1995	Cassis, France	C. A. Possamaï, H. Ross, B. Scharf, R. Teghtsoonian, and L. M. Ward
1996	Padua, Italy	S. C. Masin
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1998	Québec, Canada	S. Grondin, Y. Lacouture, and R. Rousseau
1999	Tempe (AZ), USA	P. R. Killeen and W. R. Uttal
2000	Strasbourg, France	C. Bonnet
2001	Leipzig, Germany	E. Sommerfeld, T. Lachmann, and R. Kompass
2002	Rio de Janeiro, Brazil	J. A. da Silva, E. H. Matsushima, and N. P. Ribero-Philo
2003	Larnaca, Cyprus	B. Berglund and E. Borg
2004	Coimbra, Portugal	A. M. Oliveira, M. Teixeira, G. Borgess, and M. J. Ferro
2005	Traverse City (MI), USA	J. S. Monahan, S. M. Sheffert, and J. T. Townsend
2006	St. Albans, UK	D. E. Kornbrot, R. M. Msefti, and A. W. MacRae
2007	Tokyo, Japan	S. Mori, T. Miyaoka, and W. Wong
2008	Toronto, Canada	B. A. Schneider, B. M. Ben-David, S. Parker, and W. Wong
2009	Galway, Ireland	M. A. Elliott, S. Antonijević, P.Berthand, P. Mulcahy, C. Martyn, B. Bargery, and H. Schmidt
2010	Padua, Italy	A. Bastianelli and G. Vidotto
2011	Ra'anana, Israel	D. Algom, D. Zakay, E. Chajut, S. Shaki, Y. Mama, and V. Shakuf
2012	Ottawa, Canada	S. R. Carroll, E. Gallitto, C. Leth-Steensen, W.M. Petrusic, J. R. Schoenherr, and D. A. Verger

Contents

Preface

It is pleasure and honor to host this year's Annual Meeting of the International Society for Psychophysics, *Fechner Day 2013*, in Freiburg. We feel that it is a well-deserved honor for Freiburg. Indeed, in spite of its somewhat eccentric geographic location, Freiburg occupies an important place in the map of Germany's academic and intellectual life. Freiburg University has a long record of famous names and significant contributions to scholarship and science of not only German, but truly international dimensions.

Let us mention, first of all, Edmund Husserl's phenomenology, a direction of thought that profoundly influenced European philosophy, but also adjacent fields of study such as psychology, anthropology, aesthetics, and finds a comeback in merging with cognitive science and consciousness studies. Freiburg has its place in the history of mathematics, with Ernst Zermelo and his significant contributions to the foundations of the set theory, and in natural sciences—e.g. in physics with Gustav Mie, known for his works in optics and fundamental theory of matter and gravitation; and in chemistry with Georg von Hévésy, the founding father of nuclear medicine. Again on the side of humanities, we should also name the late Friedrich von Hayek, who is known mostly for his economical and philosophical writings, but whose original contribution to theoretical psychology, *The Sensory Order*, should not remain unmentioned.

Closer to and more specifically for the fields of psychophysics and sensory physiology, at least two names should be mentioned, those of Hugo Münsterberg and Johannes von Kries.

Hugo Münsterberg (1863–1916), after his studies with Wundt in Leipzig, and then in Heidelberg, spent four years in Freiburg before he moved (by invitation of William James) to Harvard University, USA, where he stayed until his untimely death. His Freiburg years were filled with creative research in experimental psychology and psychophysiology, as he built up his own laboratory which, at that time, was only the fourth experimental psychology laboratory in Germany [1]. If E. G. Boring named Münsterberg the "founder of applied psychology" [2], it may seem a little bit high-pitched, but not unjustly exaggerated.

Johannes von Kries (1853–1928), who studied physiology and medicine at several universities in Germany and Switzerland, and spent a year with Helmholtz in Berlin, had a chair for physiology in Freiburg since 1880 for the rest of his life. He worked not only in his own fields of specialisation, muscle physiology and physiology of color vision; being a person of broad intellectual and philosophical interests, he was occupied with foundational problems of natural sciences, including theory of measurement and probability theory. On the same basis, von Kries had to become one of the most severe critics of Fechner's concept of "measurement of sensations." [3]

Surely the list of illustrious names could be continued—omissions do not imply less importance!—but let us turn from historical dimensions to actual present.

* * *

Thematic diversity is a constant feature of Fechner Day conferences, and this is true for this year's Fechner Day again. We envisage a rich program, consisting of about fifty oral and more than forty poster presentations—experimental reports, theoretical developments, and philosophical or historical investigations—, authored and co-authored by no less than 160 colleagues from eighteen countries world-wide. The topics of five theme sessions range from novel treatments of traditional psychophysical problems up to recently opening fields of research. We are pleased to see contributions from the fields of applied and clinical psychophysics, and strengthening links to related disciplines of psychophysiology, neurophysiology, and cognitive neuroscience.

This rich scientific program is highlighted by two invited lectures: by Professor Gunnar Borg (University of Stockholm), discussing methodological problems of measurement of subjective experience, and by Professor Gary Hatfield (University of Pennsylvania), presenting philosophical perspective on sensory experience and problems of perception in general.

A special symposium is dedicated to the intellectual legacy of Ernst Mach, the Austrian physicist, to commemorate the 175th anniversary of his birth (1838). Mach's contributions to psychophysics are well-known, but there is more. The aim of the symposium is not only to remember Mach's experimental research in optics and acoustics, and his discoveries in the field of sensory physiology, but also to acknowledge his impact on philosophy of science and to evaluate his influence on other fields, such as Gestalt psychology, pedagogy, and didactics of science.

* * *

We wish to thank all those who helped us in conceptualizing and organizing this conference: members of the Executive Committee of the ISP (p. iii) for their ideas and suggestions, and also organizers of earlier Fechner Days for sharing their experience with us. Special thanks to our assistants for their help: Oksana Gutina, Hanna Lehnen, Anna Sarikaya, and Jakob Pacer. Also, a financial donation and administrative-technical support from the Institute for Frontier Areas of Psychology and Mental Health in Freiburg are to be thankfully acknowledged.

We wish all participants an interesting meeting, thought-provoking discussions, inspiring exchange of ideas, and enjoyable social events. Welcome to Freiburg!

Program committee *Fechner Day 2013*:

Jiří Wackermann, Marc Wittmann, and Wolfgang Skrandies

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Invited lectures

Psychophysics and intersubjectivity

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Psychophysics has always focused on methods. Identification has dealt with "object identification" and scaling with determinations of S–R-functions. However, identification must also deal with "magnitude identification" as a part of scaling.

Intersubjectivity deals with problems about interindividual agreements of experiences. What are the similarities between people that we can use to formulate laws about how we perceive the world? The philosopher Quine used to emphasize the importance of sensory evidence. His demands for intersubjectivity were: similarities of sensory organs and observation sentences. In his last book [1] he omits, unfortunately, the demand on similarities of sensory organs.

In psychophysics we can agree upon simple relations and the meaning of numbers, making it possible to determine S–R-functions. But there are great individual differences in magnitude estimations.

We can also agree upon the meaning of many verbal expressions, such as 'Weak' and 'Strong'. (According to Wittgenstein a private language cannot exist). Words function well for level identifications but not for S–R-functions, since words only are rank ordered. A psychophysical scale that shall function in most situations, and for estimation and production, has to combine the advantages of numbers with the advantages of words (using our inner "mental yardstick"). "Level Anchored Ratio Scales" are very useful! Our general scales must also be applicable to inner stimuli and "interoceptors". – We then find that we must include two extra parameters in the power function.[2]

For scale construction it is important to know the size of the dynamic range and the position of anchors. Many scales have only anchors in the beginning and the end, e.g. 'Nothing at all' followed by 'Extremely Weak' and then at max., 'Highest imaginable'. It is very important that the last anchor has a great intersubjective validity, since it will function as a main reference level, a "fixed point" and unit of measurement. 'Highest imaginable' is not a good anchor since it is not a schematized conception. Much better is 'Maximal' referring to a sensation that most people have experienced, e.g. a maximal heaviness. There are very few such schematized conceptions since most perceptions are influenced by pain at extremely high intensities. There have also to be anchors, in congruence with numbers, between the end points, e.g. for recommendations of just right intensities, and then possibilities to give ratings above 'Max' if an experience is higher than expected.

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Why does perceptual realism matter?

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Philosophy has long debated perceptual realism.[1] As a philosophical position, perceptual realism asserts that perception has as its object (whether immediate or mediate) something mind independent. Within this boundary, various perceptual realisms have arisen. Some standard types include: (1) *naive direct realism*, according to which external objects are directly available to consciousness without phenomenal, representational, or subjective mediation[2]; (2) *representative realism*, which holds that we see or apprehend representations that have the properties they (allegedly) seem to have, such as elliptical brown patches in relation to pennies and trapezoidally shaped color patches for tables, and that we infer (or otherwise cognitively affirm) actually existing material objects from these phenomenally immediate representations[3]; (3) *content physicalism*, which proposes that we see external objects in virtue of having visual representations with information content that represents their physical properties accurately, avoiding any subjective aspect or subjectively qualified mediating content[4]; and (4) *critical direct realism*, according to which actually existing material objects are presented to us through their appearances, allowing us to perceive those objects directly through the mediating appearances or representations of them.[5]

Considered philosophically, these positions have reasonably well-known benefits and problems, concerning their metaphysical, epistemological, and phenomenal plausibility. They also have implications for the psychology of perception, concerning the immediate object of perception and the psychological processes that yield perception. For example, naive realism asserts that the conscious mind directly confronts a distal material object, without subjective aspect. It has difficulty accounting for the effects of viewpoint and the phenomenal character of perceived color (even if phenomenally located in surfaces). Representative realism posits actually existing color patches as the immediate object of perception. These may be non-mental items, as in the original sense-data positions[3], or mental items.[6] This position entails that such items are direct objects of acquaintance, available to consciousness, and are the basis for a cognitive process, whether inferential or merely habitual, that yields the mediate perception of an external object. Content physicalism asserts that perceivers are aware of external objects by being aware of their physical properties (as described by the science of physics or, for spatial properties, as characterized in a macro-level physical description of the spatial layout). It proposes a specific view of the metaphysics of color, that the color property reduces to surface spectral reflectance. Content physicalism also has difficulty explaining any subjective aspects of spatial perception beyond point of view. Critical direct realism proposes that phenomenal contents and cognitive affirmations yield direct perceptions of external objects. Psychological questions may arise about the status of this phenomenal content and cognitive affirmation, and also about the significance of considering perception to be "direct" in this manner.

Such implications form a basis for finding one or another position preferable, theoretically or empirically. Conversely, initial preference for one or another position may influence theoretical conceptions and influence the direction of empirical research. As an example of the latter, a physical-content view of color as a surface property yields a conception according to which metameric matching entails a loss of information and renders some colors imperceptible or else subject to constant illusion. (If each surface spectral reflectance is a distinct chromatic color, then,

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if two appear the same, one is illusory and the "real" color of that surface spectral reflectance goes unperceived.) This attitude toward what color is leads to specific types of modeling, and to specific conceptions of what counts as successful color perception. As an example of the former, the difficulty that naive-realist, representative-realist, and content-physicalist positions have with explaining certain global facts about space perception may count against those positions and in favor of critical direct realism. Such facts include the convergence of railway tracks or roadways with distance. The amount of such convergence is not specified by geometrical optics or by physical or object facts alone (against naive realism and content physicalism). The amount of convergence must be accounted for subjectively, but does not coincide with the traditional sense data of representative realism, which usually took the initial object of perception to be equivalent to a perspective projection.

Perceptual realism matters for its implications concerning how the object of perception is conceived and how it enters into a perceptual relation between perceiver and world.

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Theme session 1

Effects of movement, emotion, and embodiment on the perception of time

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Subjective time is tied to the mental status of the beholder: it reflects one's cognitive, bodily and emotional state. Body anatomy and bodily processes have an intrinsic role in shaping faculties of the mind such as emotion, cognition, and self-awareness. Related to several attempts to directly relate rhythms of the body with temporal processes in perception and action, embodied concepts of time perception have recently been proposed suggesting that the experience of time is related to emotional and visceral processes as they share common neural systems[1].

An early proposal linked to one of the first psychophysical laboratories situated in Freiburg was formulated in 1889 by Hugo Münsterberg[2]. He reported that when temporal intervals ranging in duration between 6 and 60 s had to be reproduced, the accuracy in temporal reproduction was higher when the onset and the offset of the intervals coincided with the onset of breathing in. Temporal reproduction was less accurate when temporal intervals started at other points in time not systematically related to the breathing cycle. Münsterberg therefore concluded that the sense of time relies on the sensation of tension in different organs which are caused by muscle contractions.

This session touches some aspects of these issues by showing how conceptual knowledge of movement and speed[3] as well as the actual experience of movement[4] influence the perception of duration. Furthermore, it will be shown how emotional content affects time estimates as affective reactions lead to an overestimation of duration[5]. In addition, clinical work will be presented showing how the impairment in temporal-order judgment is correlated with emotional withdrawal in schizophrenic patients[6]. The contributions of this session highlight evidence of how the experience of time is related to the dynamics of the environment and to embodied temporal processes of the beholder.

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Movement and speed associated with a stimulus affect the estimation of its duration

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Participants belonging to different age groups ranging from 6 to 30 years were presented with stimuli and were asked prospectively to estimate the exposure duration of each stimuli. Exposure durations were either 3 or 8 seconds and duration estimation was done via the reproduction method. The target stimulus was presented and participants were asked to stop it when they felt that the original exposure duration was over. This method enabled young children to overcome the language barrier. The stimuli which were presented were a sport car or a truck, a bicycle or a motorbike. Each stimulus was presented as either a static or as a moving one. The sizes of all the stimuli were matched so that each had the same projection area on the retina. Exposure durations and movement rate were the same in all respective conditions. The findings obtained revealed that children estimations were influenced by whether or not the stimulus was static or moving and by the type of the stimulus. Exposure durations of static stimuli were estimated to be longer than that of moving ones and exposure durations of fast stimuli (i.e., a sport car and a motorbike) were estimated to be shorter than those of respective slow stimuli (i.e., a bicycle and a truck). As for adults, exposure durations were not influenced by these factors. The findings suggest that duration estimation is not dependent on a cognitive-perceptual process only. It seems that children are influenced by the knowledge they have about stimuli and they estimate durations by referring to the relations between time, speed and distance, because they can't refer to time by itself. Being able to handle time as an abstract concept by itself demands some cognitive maturation. The implications of the findings for understanding duration judgment and the impact of embodiment on it are discussed.

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From eye to hand: implicit enaction expands subjective tactile duration

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One notion central to the 'embodied' and 'enactive' views is that perceptual and cognitive processes are subject to the constrains of action, or intended action[1]. So is time perception[2,3]. For instance, most of us would have experienced 'chronostasis', an illusion of time in which a clock's second hand appears to stand still when one directs gaze from elsewhere onto it[4]. The evidence of action influencing time perception suggests that subjective time is not a pure perceptual phenomenon, but can only be appropriately understood by taking the larger context of the perception-action loop into consideration. Here we tested whether action context, including action and (explicitly or implicitly) intended action, influences time perception of sensory events in a wide sensorimotor loop, not limiting to the timing of action or the duration of an event relating to the action goals.

To this end, we induced implicit action context in participants by using a near-body moving object, a 'ball', and measured participants' tactile temporal bisection performance. We found participants overestimated the tactile duration when the ball was approaching or moving laterally, with the overestimation being more marked for the approaching movement. The results suggest that the near-body ball movement spontaneously activates action preparation, with processes of action planning distorting the subjective time of sensory events taking place in the sensorimotor loop. It should be noted, action contexts or types of visual movements (e.g., looming vs. receding) may also cause an increase in arousal, which could potentially contribute to the duration distortion[5,6]. However, these accounts were ruled out by a further comparison between approaching and receding movements on subjective tactile duration judgments.

To further support our 'embodied view' of subjective duration expansion, we examined whether the subjective time expansion would be diminished when the activation of an embodied reaction is inhibited. We presented participants with approaching movements while they held two lightweight objects in their hands, and compared their tactile duration judgments under this hands-occupied condition to their judgments in the hands-free approaching-movement and the static baseline conditions. The overestimation was diminished in the hands-occupied approaching condition. The findings are consistent with recent 'embodiment' views on perception and action[7,8], according to which embodied reactions increase the speed of sensory processing, and, consequently, expand subjective time in the sensorimotor loop.

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Aspects of emotional contents and movement perception on subjective time experience

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Artwork compositions can be studied according to different criteria involving hedonic effects, compositional elements and emotional contents. Implied movement in abstract and figurative artworks has been discussed in the scientific literature [1–4] and are related to time perception. Abstract and figurative paintings representing human beings implying more movement have been estimated longer than those implying less movement. Photographs of ballerina sculptures by the impressionist Edgar Degas in different ballet postures, implying movements of distinct intensities, modulate time perception [5]. Another study [6] examined embodiment mechanisms associated with time distortions. Temporal bisection task data showed that the duration was judged longer for Degas' ballerinas requiring more movement (high-arousal body posture) than for the ballerinas requiring less movement (low-arousal body posture). However, the magnitude of the time distortions was relatively greater for the shorter (0.4–1.6 s) than for the longer (2–8 s) duration of stimuli exposures. These data suggest that the lengthening effect was mediated by an arousal effect of limited duration on the speed of the internal clock system. The effects of movement perception on subjective time related to arousal levels were also examined with individuals exposed to artwork from different artistic schools [7]. Impressionist and cubist artworks were exposed for different duration and participants were asked to reproduce the time exposures in the prospective paradigm. Time distortions, related to higher arousal and implied movement, were obtained when 20 abstract paintings were exposed for 3 s (Experiment 1). However, only cubist paintings representing human forms caused time distortions. Experiment 2 further verified if these time distortions were related to the movement perception or arousal levels exposing only these cubist paintings for 3 and 9 s as the arousal effects were transient upper than 3 s. Overestimation were observed in the painting with greater arousal and movement scores only when it was exposed for 9 s. The results showed that implied movement in abstract human figures oversized the effects of arousal levels and there is an interaction of paintings pictorial characteristics to time perception. The conclusion is that the aesthetic experience of art is not limited to visual perception that causes different levels of arousal (emotions) in the individuals. Embodiment mechanisms were also important to explain different aspects of work-spectator relation by activating different brain areas which represent the observed movement.

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Temporal order judgements are impaired in patients with schizophrenia: A link with emotional withdrawal?

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The sense of time continuity and of present time are both impaired in patients with schizophrenia, and question the mechanisms of timing. Several studies have shown that these patients are impaired in discriminating between simultaneous and asynchronous events, leading to enlarged windows of temporal simultaneity[1]. We showed that patients may also be impaired at a more elementary level. During the tasks, subjects decide whether two squares are displayed simultaneously or asynchronously, and give their response by hitting a left or right response key. We repeatedly showed that when stimuli are asynchronous and displayed on opposite sides, manual responses are biased to the side of either the first or second stimulus[2]. Such a bias allowed us to show that patients distinguish events in time at an implicit level even when explicitly judging such events to be synchronous. In addition, their implicit responses differ qualitatively from those observed in controls. For asynchronies eliciting 'simultaneous' judgements, patients' responses are biased to the side of the 1st square whereas controls' responses are biased to the side of the 2nd square. We proposed that in controls, elementary predictive mechanisms allow anticipation of upcoming events, whereas patients process squares as if isolated rather than following each other. This leads us to question how patients judge temporal order. What we already know is that patients are able to discriminate between simultaneous and asynchronous stimuli when the Stimulus Onset Asynchrony (SOA) is large enough. However, it is possible to detect an asynchrony between two events without being able to tell about their temporal order[3]. Here we directly compare the temporal order judgments and simultaneity/asynchrony discrimination in the same patients.

Two squares were displayed on the screen either simultaneously or with an asynchrony of 24 to 96 ms. In one session 18 patients and 18 controls made a temporal order judgement and in the other they discriminated between simultaneous or asynchronous stimuli. Controls reached similar performance in the two tasks at asynchronies above 50 ms, whereas patients showed a large impairment in temporal order judgment selectively. Moreover the impairment in temporal order judgment was correlated with emotional withdrawal in patients.

The results confirm that patients with schizophrenia have a difficulty to determine temporal order, even for SOAs leading to a clear perception of asynchrony. The link with clinical symptoms suggests this impairment might mediate the loss of 'vital dynamism' reported in early descriptions of schizophrenia. Patients would not follow events automatically (possibly underlying the disruption of the sense of time continuity), and would be impaired in structuring events in time at a conscious level.

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Theme session 2

Perception, cognition, and brain activity: Introductory remarks

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Human sensory and higher information processing can be studied by non-invasive measurements of electrical brain activity that reflects mass activity originating from many neurons simultaneously. Commonly we use scalp recordings in healthy volunteers and patients in order to find neural correlates of perceptual or cognitive processing.

Electrophysiological recording is related to other methods: with modern imaging techniques (CT, structural or functional MRI, PET), the determination of anatomical brain structures or of hemodynamical responses to different processing demands is available at high spatial resolution, but typically has to rely on longer integration times in order to derive significant signals that reflect changes in metabolic responses. However, different from metabolic brain imaging methods like fMRI or PET, non-invasive electrophysiological measurements (or measurements of the accompanying magnetic fields, MEG) possess high temporal resolution in the order of milliseconds. Thus, techniques to quantify electrical brain activity are unsurpassed when functional validity is required in order to characterize central nervous processing in man [1].

One successful example of this approach is a series of psychophysical and electrophysiological studies on the differences of visual information processing when the upper and lower halves of the human retina are compared. Behavioral data on critical flicker fusion, contrast sensitivity, pattern discrimination or double-flash discrimination have direct neurophysiological correlates revealed by non-invasive recordings of electroretinograms and visual evoked brain activity [2].

In this theme session we show how perception and cognition are related to electrical brain activity measured in healthy subjects as well as in patients. Non-invasive measurement of human brain activity offers the possibility to monitor brain processes in real time which may complement behavior measures of perception and cognitive processes.

The contributions to this session illustrate the fundamentals of analyzing human electrophysiological brain activity, and relate behavioral data ranging from basic perceptual mechanisms (vision, hearing, pain) to higher information processing like learning and language to human brain processes [3–6].

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EEG correlates of multistable perception

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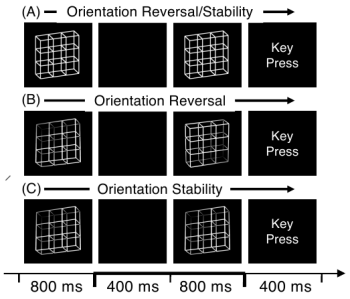
When we look at an ambiguous figure, our perception is unstable and alternates spontaneously between different interpretations [1]. Studying the mechanisms underlying this phenomenon is difficult because the time instant of the endogenous alternation must be known and observers key press is too imprecise ($\pm$100 ms) [2] for this purpose.



We have developed the "Onset-Paradigm" to circumvent this problem: Participants viewed in different experiments either ambiguous Necker lattices (Fig. 1A) or unambiguous lattices (Fig. 1B/C) and compared the 3D perspective of successively presented stimuli. In separate experimental conditions they indicated in a go/nogo task either a perceived perspective reversal (Fig 1A/B) or perceived stability (Fig 1A/C) across successive stimulus presentations by key press in the inter-stimulus interval (ISI) after the respective perceptual event.

The Onset-Paradigm successfully locked endogenous perceptual reversals of ambiguous figures to the stimulus onset with a precision of about $\pm$30 ms, revealing a chain of EEG components. This chain turned out to be closely similar to a chain of EEG signatures, related to exogenously induced reversals of unambiguous stimulus variants, with three exceptions: (1) An occipital "Reversal Positivity" 130 ms after stimulus onset and (2) a concurrently starting left-hemispheric occipital to frontopolar decrease in alpha-band activity, lasting for about 60 ms, are restricted to endogenous reversals. (3) All subsequent signatures are delayed with endogenous compared to exogenously induced reversals. The smallest delay of 40 ms is visible in the earliest component occurring with both types of reversals, the occipital/parietal "Reversal Negativity", starting at 260 ms (Necker lattice) and at 220 ms (unambiguous lattices). And (4), most remarkably, endogenous perceptual reversals are anticipated by right-central modulations in the gamma frequency band in the ISI 200 ms before an endogenous perceptual reversal [2].

Our results have been replicated by others (for a review see Ref. 2). We interpret them as follows: The gamma band modulations anteceding a perceptual reversal may indicate a brain state of maximal instability that occurs at the transition from one perceptually stable brain state to the other. The subsequent Reversal Positivity then may reflect a conflict arising from the ambiguity of the visual information at a relatively early processing step within the visual cortex. This putative conflict lasts about 40 ms and may involve posterior visual but also more anterior cognitive brain areas, as reflected by the alpha-band decrease. A late parietal positivity may then indicate awareness of the resulting perceptual reversal. Further studies have to relate our results to reversals during continuous observation.

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Electrophysiological studies on perception and learning

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In this contribution we report on various different and independent studies on perceptual learning and on learning of meaningful material. We investigated perceptual learning in 85 healthy adults with stereoscopic information contained in dynamic random dot stimuli or with vernier targets (hyperacuity targets). Stimuli were flashed simultaneously at 8 locations at different eccentricities, and subjects had to detect a target in an *8 Alternative Forced Choice* task. When *training* at a given eccentricity, stimuli at the other eccentricity served as a *no training* control condition. Viewing of visual targets for about 20 minutes resulted in a significant increase of discrimination performance only for the trained stimuli (significant interaction between training and time). Thus, learning is position specific: improved performance can be demonstrated only when test and training stimuli are presented to the same retinal areas (or have similar physical features like stimulus orientation). In combination with our electrophysiological results on significant changes of brain activity induced by perceptual training with hyperacuity targets and with 3D stimuli, such data illustrate how perceptual training induces stimulus and visual field specific neural plasticity in adult subjects. These data complement our results on perceptual learning where both psychophysical and electrophysiological changes were observed after perceptual training [1–3].

In other experiments we studied human semantic learning in three groups of healthy German adults. Forty Kanji characters were presented visually in random order before and after a learning session of 20 minutes duration. In the learning period subjects acquired the meaning of 20 of the stimuli while the other stimuli served as unlearned control condition. Learning performance was tested at the end of the experiment. All subjects learned stimulus meaning with a recall rate of more than 90%. The analysis of stimulus-related electrical brain activity revealed that learning was accompanied by significant changes of the pattern of activation over primary visual areas. Since the physical characteristics of the visual stimuli were identical before and after learning, our results represent neurophysiological changes that were induced exclusively by higher-order, semantic learning. Similar to the results on perceptual learning described above, also learning of semantic meaning occurs very rapidly within 20 minutes [4]. We performed additional experiments on a group of Japanese adults who had to learn German words. These data resulted in very similar effects (high recall rates; electrophysiological changes at short latencies).

Our results on semantic learning are congruent with previous reports on human perceptual learning. With simple, meaningless visual stimuli, brain activity occurring at early processing times changed during a visual discrimination tasks with with stereoscopic [1] or with hyperacuity [2,3] stimuli. The electrophysiological data indicate that learning processes are reflected by systematic changes of electrical brain activity originating presumably in primary visual areas.

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Agency and ownership are independent components of auditory-verbal self-monitoring

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'Sensing the self' requires a subject to be able to distinguish self-generated from self–independent events. In psychiatric conditions such as psychosis, this sense of self is frequently impaired. Already Helmholtz [1] suggested that the comparison of an efferent copy of motor actions with afferent sensory information allows a reliable sense of being or not being the cause of a sensory event. However, apart from such causal elements, other functions such as memory-based recognition may also play an important role.

The presented experiment was designed to separate the normal neurobiological fingerprints of feelings of agency (that implies causality) and ownership (that implies memory) using evoked potentials. During the experiment, 13 healthy subject read visually presented neutral single words, while auditory feedback was delivered through a headphone. This feedback was hearing the same word either in the subjects own voice or spoken by a foreign voice of the same sex, which altered the presence of ownership of the auditory input. Additionally, subjects heard self- and foreign spoken words without reading, which removed the presence of agency in the percept. A reading without hearing condition served to control for speech related artifacts. Average ERPs were computed for all conditions and topographically compared following a 2×2 (with vs. without agency by with vs. without ownership) design.

In the N100 period (86–172 ms), we found significant topographic ERP effects of agency and ownership. The configuration of the ERP fields of the two effects suggested that they are nearly orthogonal. In a later time window (174–400 ms) there were also main effects of agency and ownership, but this time with a strong topographic similarity, suggesting that both effects were additive in this time period and shared a largely common mechanism.

This finding may be relevant for the understanding of the neurobiology of schizophrenia: In schizophrenia, a cluster of symptoms is partly characterized by a deficient sense of self (e.g. verbal hallucinations, ego-disturbances such as thought insertion and withdrawal, or feelings of being made). We suggest that loss of agency alone may lead to symptoms of ego-disturbances. Additionally, if ownership is affected, hallucination-type symptoms may result.

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Methodological aspects of connectivity analyses of the neuromatrix of pain

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Pain is a subjective phenomenon, produced by the interactions of a complex and dynamic network of brain structures termed the brain's neuromatrix of pain (BNMP), and composed of different cortical and subcortical brain areas. Although EEG/MEG and fMRI allow measurement and localization of brain activity on different spatial and temporal scales, interactions between activated brain areas cannot be directly measured. Their study requires sophisticated analysis tools and modelling that use measured brain activity as input data.

The concept of Granger Causality (GC) and the Partial Directed Coherence (PDC) enable such an interaction analysis by using EEG/MEG or fMRI. GC works in the time domain whereas PDC is frequency-selective. Both time-variant GC and PDC are based on a time-variant, multivariate autoregressive (AR) modelling of the brain activity to be analysed. The extraction of parameters and their statistical testing allows the detection of significant interactions between electrode (sensor) and/or source activities. The resulting interaction networks are complex and in particular the time evolution of interaction networks is difficult to quantify and to interpret. Graph theoretical methods have been successfully applied for analysis of interaction networks. Motif detection is one of these approaches.

Two experiments are presented which analyze the BNMP based on evoked potentials (EPs). In the first experiment the spatio-temporal dynamic of pain processing caused by repetitive pain stimulation (heat pulse stimulation, laser beam) was investigated by means of time-variant interaction analysis. The time-variant Granger Causality Index (GCI) was computed by using the general linear Kalman filter approach to compute networks of directed interactions between the electrodes. For the base-line segment the analysis reveals a network which contains sources in the parietal regions (spatial attention) and sinks in the prefrontal regions (involvement of working memory, attentional processes) which are more pronounced on the site contralateral to stimulation. For the subsequent N2 and P2 segments, interaction patterns were found that involve the somatosensory and other additional regions (serial/parallel processing of somatosensory and affective dimensions of pain). The interaction network found for the P3 segment might contribute to the generation of the intensity rating of stimuli requested from the subjects.

In a second experiment the differences in pain processing between patients with major depression (MD) and healthy subjects were studied. Stimuli consisted of a bipolar rectangular current pulse. and the EEG before and after stimulation (EP) was analyzed. The time-invariant generalized PDC in the frequency range 1–13Hz was used to construct interaction networks. It was observed that the interactions of the MD patients showed fewer changes in comparison to the controls. This finding might explain why the MD patients show increased thresholds to external stimuli. Additionally, the PDC differed according to which side was stimulated (relationship between left- and right-hemispheric processing might be altered in MD). The interaction networks were analyzed by motif detection approaches and the results confirm previous findings.

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Theme session 3

Complementarity in cognition

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It has been an old idea by Bohr that central conceptual features of quantum theory, such as complementarity, are also of pivotal significance far exceeding the domain of physics. In fact, Bohr became familiar with the idea through the psychologist Edgar Rubin and, more indirectly, William James, and immediately saw its potential for quantum physics. Although Bohr was always convinced of the extraphysical relevance of complementarity, he never elaborated this idea in concrete detail, and for a long time after him no one else did so either. This situation has changed: there are now a number of research programs generalizing key notions of quantum theory in a way that makes them applicable beyond physics.

Of particular interest are approaches that have been developed in order to pick up Bohr's proposal with respect to psychology and cognitive science. The first steps in this direction were made by the group of Aerts in the early 1990s[1], using non-distributive propositional lattices to address quantum-like behavior in non-quantum systems. Alternative approaches have been initiated by Atmanspacher *et al.*[2], outlining an algebraic framework with non-commuting operations, and Khrennikov[3], focusing on non-classical probabilities. A recent monograph by Busemeyer and Bruza[4] provides a good overview of the present state of the art, and a brandnew special issue of *Topics in Cognitive Science*[5] sketches novel developments.

Intuitively, it is quite straightforward to understand why non-commuting operations or non-Boolean logic should be relevant, even inevitable, for mental systems that have nothing to do with quantum physics. Simply speaking, the non-commutativity of operations means nothing else than that the sequence, in which operations are applied, matters for the final result. And non-Boolean logic refers to propositions that may have unsharp truth values beyond yes or no, shades of plausibility or credibility as it were. Both versions obviously abound in psychology and cognitive science (and in everyday life as well).

Several kinds of quantum-based concepts have been applied in psychology so far. Two of them are the non-commutativity of operations and the non-Boolean nature of propositional calculi. A third key idea derives from so-called Bell inequalities whose empirical violation can indicate effects of non-separability or non-locality. And last but not least, combining incompatible measurements can entail that classical probability, and Bayes theorem, become inapplicable. The presentations in this theme session will discuss examples for all these features.

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Order effects in sequential measurements of non-commuting psychological observables

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One of the pioneers of research on sequential measurements in psychology stated: "One of the factors that inhibited our progress in understanding order effects has been the lack of a theoretical structure within which to investigate the mechanisms by which they might occur."[1] This contribution presents an attempt toward such a theoretical basis.

Sequential measurements of non-commuting observables produce order effects that are well-known in quantum physics. But their conceptual basis, a significant measurement interaction, is relevant for far more general situations in which the sequence in which measurement operations act upon the state of a system makes a difference for the results obtained. One reason is that a measurement operation changes the state of the measured system such that a subsequent measurement operation effectively acts on another state. Related to this, a measurement is not simply the registration of a pre-existing fact, but also establishes the fact that is registered.

We argue that non-commutativity is ubiquitous in psychology where almost every interaction with a mental system changes that system in an uncontrollable fashion. Psychological order effects for sequential measurements are therefore to be expected as a rule, although states, observables and their dynamics have nothing to do with quantum physics. The mathematical feature of non-commuting observables and its ramifications can be fruitfully applied to model psychological situations where order effects abound.

In this contribution we focus on the theoretical basis of such effects. We classify several families of order effects which focus on shifted mean values of measurement distributions and relate them to psychological observations[2–4]. Moreover, we predict additional effects yet to be discovered empirically, which are related to Heisenberg-type uncertainties and correlational effects.

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Quantum models of cognition and decision

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Quantum cognition concerns the application of the mathematical principles from quantum theory to human judgment and decision making behavior. At first sight it may seem rather far fetched to draw connections between human cognition on the one hand, and quantum mechanics on the other. Yet there are good scientific reasons for doing so, which is leading a growing number of researchers to examine quantum theory as a way to understand perplexing findings and stubborn problems within their own fields—hence this new field. Given the nascent state of this field, some words of justification are warranted. The research just mentioned is not concerned with modeling the brain using quantum mechanics, nor is it directly concerned with the idea of the brain as a quantum computer. Instead it turns to quantum theory as a fresh conceptual framework for explaining empirical puzzles, as well as a rich new source of alternative formal tools.

There are two aspects of quantum theory which open the door to addressing problems facing cognition and decision in a totally new light. The first is known as "contextuality" of judgments and decisions which is captured in quantum theory by the idea of "interference." The context generated by making a first judgment or decision interferes with subsequent judgments or decisions to produce order effects, so that judgments and decisions are non-commutative. The second aspect relates to "quantum entanglement." Entanglement is a phenomenon whereby making an observation on one part of the system affects the state in another part of the system, even if the respective systems are supposed to be cognitively separate. The crucial point about entanglement relevant to cognition is that entangled systems cannot be validly decomposed and modeled as separate subsystems. This opens the door to developing quantum-like models of cognitive phenomena which are not decompositional in nature. Quantum cognition provides a unified and powerful explanation for a wide variety of paradoxes found in human cognition and decision ranging across findings from attitudes, inference, causal reasoning, decision making, conceptual combinations, memory recognition, and associative memory.

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Complementarity in cognition entailed by bounded rationality

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Recent research has revealed intriguing parallels between quantum physics and cognitive sciences dealing with concepts, vagueness, and prototypicality[1]. These parallels become obvious when one of the key features of quantum theory is considered: the concept of *complementarity*.

Two observables are called complementary when a pure state cannot be a common eigenstate of both observables, which is not possible in classical physics where pure states are identified with points in a phase space that are common eigenstates of every observable. The situation is different, however, if one also takes statistical states, namely dispersive probability measures upon phase space, into account. Then, the concept of a quantum mechanical eigenstate applies straightforwardly to an operationally restricted state space resulting from a phase space *coarse-graining* into epistemic equivalence classes. This 'epistemic quantization' of classical dynamical systems introduced by beim Graben *et al*.[2] is nicely illustrated by Foulis' firefly box[3] where an observer is only able to tell the glowing firefly's position either as to the right or to the left with respect to the front window or to the front or to the bottom with respect to the side window.

Here, we suggest to regard this operational constraint, preventing the simultaneous assessment of two complementary perspectives, being caused by limited resources as in *bounded rationality*[4]. Considering the origin of complementary in cognition as a kind of bounded rationality leads to orthomodular lattices by pasting together two (or more) partial Boolean algebras as demonstrated with Foulis' firefly box[3,5].

However, Foulis' example only presents a static picture for the emergence of quantum-like descriptions from coarse-grained classical systems. If the firefly were exploring a chaotic itinerary, the dynamics would have to be taken into account as well. As beim Graben *et al*.[2] have demonstrated, a chaotic itinerary yields a *dynamic refinement* of the original coarse-graining that converges towards single points in phase space through the limit of continuous observations. But for general, arbitrary coarse-grainings the residual grains are not common eigenstates of any observable. Then, the Boolean partition algebras of the finest refinements of two (or more) arbitrary observables can again be pasted together along their overlaps into an orthomodular lattice[5] thus entailing the canonical Hilbert space representation exploited in quantum cognition[1].

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The relevance of Bell-type inequalities for mental systems

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Bell inequalities are inequalities for correlations between properties observed on two systems. They are derived from purely logical considerations like the transitivity law: if $a = b$ and $b = c$ then $a = c$. This implies that the number of cases where $a \neq c$ is smaller than the sum of the number of cases where $a \neq b$ and/or $b \neq c$.[1] One major assumption in the derivation is that the two measurements are performed on separate systems without any causal influence onto one another. For quantum systems, these inequalities are violated if the systems are entangled.[2]

In recent years it has been proposed that similar inequalities can be violated for mental systems. Some models, e.g. for the perception of ambiguous stimuli, have been formulated which indicate the possibility that temporal versions of Bell inequalitites can be violated.[3] In this case the measurements are performed on the same system but temporally separated. The essential assumption for the inequalities to hold is that measurements are "non-invasive": The result of the second observation should not be causally influenced by the first observation. This non-invasiveness (related to "selective influence"[4]) is difficult to achieve, and it has been speculated whether the corresponding loophole can be avoided by "adroit" measurements[5].

Several groups have recently reported violations of Bell-type inequalities in language processing, decision making, or reasoning. In all these examples, the observations have been performed on the same subject and the measurements are not necessarily non-invasive. However, one can argue that in such cases a violation of Bell-type inequalities is due to "contextual conditions." Thus, the degree of violation may be used as a measure for contextuality. It can also be shown that violations of Bell-type inequalities can be due to a "non-locality" of the meaning of a given concept in conceptual spaces.

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Theme session 4

Estimating the sensitivity in discrimination tasks: Recent challenges and advances

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A fundamental question in psychophysics is how sensitive subjects are in discriminating two stimuli on a given sensory dimension (e.g. auditory intensity, visual contrast, duration). Importantly, the sensitivity estimates should be uncontaminated by influences like response biases. For many researchers, the preferred method for measuring difference limens (DLs) is the two-interval, two-alternatives forced-choice task. A main reason for its popularity is the assumption that in this task response biases play virtually no role. However, several studies indicate that this assumption is not always valid. Subjects sometimes prefer one interval over the other ("Type A order effect"), resulting in a non-zero constant error in Fechner's terms.[1] Additionally, the sensitivity in a discrimination task was recently reported to depend on the presentation order of standard and comparison.[2,3] This "Type B order effect" presents a serious challenge for current models of discrimination performance and traditional procedures for computing DL estimates.

In the present theme session, data from psychophysical experiments and simulation studies are presented. After introducing a theoretical framework for describing Type A and Type B order effects,[4] empirical evidence for non-sensory influences on discrimination performance in different modalities, sensory dimensions, and psychophysical procedures is presented[5–7]. Improved psychophysical procedures and data analysis techniques for estimating the sensitivity in discrimination tasks are presented that take order effects and other factors not related to sensitivity into account or avoid them to some extent.[4,6,8] Potential mechanisms responsible for the observed biases are proposed[5–7], and effects of criterion changes are discussed.[9]

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Estimation of discrimination performance in 2AFC tasks

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A fundamental concept in psychophysics is the difference limen (*DL*), which quantifies the discrimination sensitivity of a participant. A common experimental procedure to estimate the *DL* is the two-alternative forced-choice (2AFC) task. On each trial of this task, a standard, s, with constant magnitude, and a comparison, c, with variable magnitude are presented one after the other. The two possible temporal orders $\langle sc\rangle$ and $\langle cs\rangle$ of s and c vary randomly from trial to trial. After each trial the participant indicates the temporal position of the larger stimulus (e.g., in a duration discrimination task, the stimulus with the longer duration). The relative frequency of judging c larger than s is usually plotted against the value of c . This frequency typically increases from zero (for relatively small values of c) to one (for relatively large values of c). The *DL* and, sometimes, the point of subjective equality (*PSE*) are computed from this 2AFC psychometric function $F(c,s)$.

There are two potential problems with this approach. First, the *DL* estimate may be contaminated by perceptual and decisional biases. Second, the *PSE* is not a meaningful measure because the constant error derived from $F(c,s)$ necessarily equals zero. It has been shown[1] that these two problems arise because $F(c,s)$ represents the average function of two underlying conditional psychometric functions, one for each order of s and c,

$$F(c,s) = \frac{F(c,s\,|\langle sc\rangle) + F(c,s\,|\langle cs\rangle)}{2}, \tag{1}$$

where $F(c,s\,|\langle sc\rangle)$ and $F(c,s\,|\langle cs\rangle)$ denote the order-conditional psychometric function for stimulus order $\langle sc\rangle$ and $\langle cs\rangle$, respectively.

Importantly, perceptual and decisional biases may affect these functions in opposite ways. To avoid these problems, it is necessary to analyze the conditional psychometric functions separately under a constraint that follows from Equation 1. This constraint implies that the average psychometric function $F(c,s)$ passes through the point $(s,0.5)$ assuming that s and c differ in the critical physical dimension (e.g., duration) only and thus are physically identical for $c = s$. This restriction applies to the majority of cases when the 2AFC task is employed; for exceptions see the work of García-Pérez and Alcalá-Quintana[2].

Computer programs in MATLAB® and R have been developed[3,4] for maximum likelihood estimation of *DL* and *PSE* from 2AFC discrimination data. These estimates are not contaminated by perceptual and decisional biases. The programs also allow the estimation of lapse rates; lapses may affect the asymptotic behavior of psychometric functions and thus also contaminate the estimation of *DL*.

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Weber Fractions and Time-Order Errors for long and short durations: Implications for modeling

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Often, discrimination sensitivity is studied by a 2AFC method, keeping one stimulus as a standard and letting the other vary around it. According to the commonly assumed Difference Model for comparison, it should not matter whether the first stimulus is fixed and the second varied (Standard-Comparison, St-Co), or vice versa (Comparison-Standard, Co-St). The aim of this study was to study Weber Fractions (WFs) and Time-Order Errors (TOEs) as a function of interval duration and presentation order of St and Co for four different types of intervals.

Using a weighted up-down procedure, in each of eight conditions 28 participants compared successve interval durations with an ISI of 900 ms: St was 100 or 1000 ms (blocked). In each block, orders St-Co and Co-St were intermixed. Thus block types for each St were [St<Co, Co>St] and [St>Co, Co<St]. Interval types (blocked) were auditory (noise bursts) or visual (LED flashes); filled, or unfilled with 3-ms markers (between-groups); with or without correctness feedback (between-groups). Upper and lower thresholds (for 75 % correct) were used to determine JND and PSE, and thereby WF = JND/St and TOE = ±(PSE−St).

For all interval types, TOEs were negative for St = 1000 ms, and positive for St = 100 ms. Feedback lowered WFs by 15–20 %, but all interactions with Feedback were nonsignificant. For auditory-unfilled (AU; only 100 ms used) WF did not differ between orders. For visual-filled (VF), WFs were significantly higher with Co-St than with St-Co; thus varying the 1st stimulus had a lesser impact on the response than varying the 2nd stimulus. In analogy with the definition of the TOE, also called Type-A effect (negative when the 1st stimulus is perceived as being of lower magnitude than an identical 2nd stimulus), this Type-B effect should be called negative. Positive Type-B effects were obtained as well: For visual-unfilled (VU) and auditory-filled (AF), WFs were highest with Co-St for 1000 ms, but with St-Co for 100 ms. The interactions of Order × Duration were highly significant. The effects refute the Difference Model, and suggest a flexible impact ratio of the 1st and the 2nd stimulus.

For AF intervals, the TOE and WF data confirm earlier results[1]. For TOEs, the results demonstrate the common effect of stimulus level – negative TOE for long, but positive TOE for short durations. These effects refute an explanation by simple response bias. The results confirm that WFs are affected by whether the 1st or the 2nd stimulus is varied, but refute the generalization that WFs are always lower with St-Co than with Co-St. For AF and VU, varying the first stimulus (order Co-St) has a higher impact on the response, as shown by smaller WFs, than varying the second (order St-Co). The Sensation Weighting Model[2,3] can account for these effects, and also for positive as well as negative TOEs.

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A new look on "order effects" and sensitivity in two-interval discrimination tasks: Decisions weights and internal noise

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In a multiple observation task like a two-interval (2I) discrimination task, the performance is limited due to two potential causes: (1) a limitation in the precision of the representation of the stimuli (e.g. due to neuronal variability in the sensory system), which is usually modeled as *internal noise*, and (2) sub-optimal integration of information from multiple sources (i.e., observation intervals).[1] This can be formalized in an observer model where the probability of selecting the stimulus presented in the second interval as having the higher value on the dimension of interest (e.g. louder or longer) is a function of a value X on the internal continuum,

$$X = w_2 (x_2 + \varepsilon_2) - w_1 (x_1 + \varepsilon_1), \tag{1}$$

where x_1 and x_2 are the stimulus values (e.g., sound pressure level, duration) presented in interval 1 and interval 2, respectively, w_1 and w_2 are the decision weights assigned to the first and second stimulus, respectively, and ε_1 and ε_2 are additive internal noise components assumed to be independent of each other and normally distributed with mean 0 and standard deviation σ_I. The participant is assumed to respond that the more intense stimulus had been presented in interval 2 if X exceeds a criterion k. Independent estimates of the decision weights and the internal noise variance can be obtained using methods of molecular psychophysics.[2] Recent studies suggested that in a 2I task the slope of the psychometric function (PMF) depends on the presentation order of standard and comparison.[3] It can be shown that the corresponding decision model is a special case of Eq. (1). In particular, the ratio of the slopes of the order-dependent PMFs is identical to the decision weight ratio. We propose the standard deviation of the (Gaussian) internal noise (σ_I) as a measure of sensitivity in the discrimination task. Unlike the slopes of the order-dependent psychometric functions, σ_I is independent of the decision weights. The model was applied to data from an experiment in which auditory duration and intensity discrimination were studied using four different 2I procedures plus a 1I procedure. Importantly, the decision weight ratio did not differ between procedures presenting a standard (i.e., stimulus with fixed value) and a procedure in which no standard was presented, where by definition no effects of the order of standard and comparison could occur. This illustrates that the so-called "Type B order effect"[3] can be viewed as a special case of unequal decision weights assigned to interval 1 and 2. The internal noise variance estimated for the 2I procedures was highly correlated to the estimated internal noise in the 1I procedure, corroborating our proposal that σ_I is a useful measure of sensitivity in a two-interval task.

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Mechanisms of stimulus discrimination: Evidence from the Type B effect

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When participants are asked to discriminate between a constant standard stimulus s and a variable comparison stimulus c, discrimination sensitivity depends on the temporal order of these stimuli and is usually higher for stimulus order $\langle sc \rangle$ than for stimulus order $\langle cs \rangle$ (Type B effect). This effect is hard to reconcile with classical models of stimulus discrimination such as Thurstonian difference models or Signal Detection Theory [1,4].

We propose another account, which is based on the idea that participants rely on an internal reference that is dynamically updated from trial to trial rather than just on the stimuli presented on a given experimental trial. This notion is formalized in the Internal Reference Model (IRM). According to IRM, the internal reference $\mathbf{I}_n$ on the present trial n is a weighted sum of the internal reference $\mathbf{I}_{n-1}$ from the previous trial $n-1$ and the internal representation of the first stimulus $\mathbf{X}_{1,n}$ on the present trial,

$$\mathbf{I}_n = g \cdot \mathbf{I}_{n-1} + (1-g) \cdot \mathbf{X}_{1,1} \tag{1}$$

with constant weight g, $0 \leq g < 1$. IRM predicts a Type B effect and this effect should increase with increasing weight g. In addition, the IRM also accounts for sequential effects on perceived magnitude in two-interval discrimination paradigms. Both predictions were confirmed in a recent series of experiments employing blocked and randomly intermixed stimulus orders [1,4].

An important question is whether the mechanism underlying the Type B effect is automatic or under participants' cognitive control. Therefore, we conducted a series of cueing experiments, in which a symbolic cue either validly indicated the temporal position of the comparison stimulus or it was neutral with respect to comparison position [2,4]. As expected, with a neutral cue, a pronounced Type B effect was observed. However, with a valid cue, this effect was considerably reduced. Thus, the mechanism underlying the Type B effect seems to be under flexible attentional control. Within IRM this may be represented as a modulation of weight g.

Finally, evidence for a dynamically updated internal reference was also found in a duration reproduction task [3,4]. Specifically, a standard and a comparison interval were presented either in order $\langle sc \rangle$ or $\langle cs \rangle$ and participants were asked to reproduce the first or second interval duration. In line with IRM's predictions, reproductions were shifted toward the mean of the comparison distribution for order $\langle cs \rangle$ but not for order $\langle sc \rangle$. In particular, long durations were underestimated and short durations were overestimated for stimulus order $\langle cs \rangle$. Hence, IRM also provides a novel account of the Vierordt effect. Furthermore, the presence of sequential effects again supported the dynamic nature of the process underlying the formation of the internal reference.

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An "I can't tell" response option prevents artifactual overestimation of the difference limen in bisection tasks

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Spatial and temporal bisection tasks are instances of the single-presentation method: Observers categorize the single stimulus that is presented on each trial. Thus, observers are asked to give "short" or "long" responses (in temporal bisection) or "left" or "right" responses (in spatial bisection). In a same–different variant of spatial bisection, observers are instead asked to give "center" or "off-center" responses. Surprisingly, and despite the fact that the stimulus set is identical in both variants and the only difference is which question observers respond to, both tasks give different results as regards estimates of the bisection point (BP) and the difference limen (DL). This may be because the conventional form of the bisection task assumes that observers can always make informed "left" or "right" judgments, while "center" responses in the same–different variant of the task prove this assumption wrong: If observers always made either a "left" or a "right" judgment, they would never respond "center". What this suggests is that "center" judgments are also made in the conventional form of the task, but they end up reported as "left" or "right" responses (by guessing) only because the response format does not allow otherwise. In other words, the conventional form of the bisection task renders "left" and "right" responses that are an inextricable mixture of authentic judgments and mere guesses.

A model has been put forward which separates sensory processes (assumed identical in both variants of the task) from response processes (which differ across variants) and explains the observed discrepancies across tasks as well as some characteristics of data collected under the conventional form of the bisection task.[1] A formal analysis of the model suggested the utility of a three-response format in which an additional response option (namely, "I can't tell") is allowed besides the conventional "left" and "right" response options. The model posits that the same sensory parameters govern judgments under both response formats (left–right vs. three-response) whereas task-specific decision/response parameters differ across formats. The model also predicts larger estimates of the DL in the simple left–right format than in the three-response format. To test these predictions, data were collected in an experiment in which 15 observers carried out a spatial bisection task under both response formats. The predictions were borne out by the data: Performance on both variants of the task could be accounted for through common sensory parameters and task-specific decision/response parameters, and DL estimates from the simple left–right format were significantly larger than estimates from the three-response format.

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Effects of criterion changes on estimates of the difference limen

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Performance on psychophysical tasks involves a sensory component to capture the stimulus and a decisional component to produce a response. The output of the sensory component depends on the stimulus in the trial, whereas the decisional component involves a criterion assumed to be independent of the stimulus and invariant across trials. Consider a single-presentation method such as a spatial bisection task. Classical Signal Detection Theory (SDT) models assume a boundary criterion, δ, such that the observer responds "left" whenever the (random) sensory effect, S, of the stimulus satisfies $S < \delta$ and responds "right" otherwise. This assumption has been proved wrong, as observers are sometimes undecided and respond "left" or "right" by guessing and not because they judged the stimulus to be left or right. SDT models have been extended to incorporate Fechner's *interval of uncertainty* to account for undecided cases.[1] This *indecision model* includes two boundaries such that the observer judges (and responds) "left" when $S < \delta_1$, judges (and responds) "right" when $S > \delta_2$, and is undecided when $\delta_1 < S < \delta_2$. In the latter case the observer must guess, potentially with some bias towards one of the options. It was shown theoretically and empirically that a far better option is to use a three-response format in which undecided cases are separately recorded through, e.g. an additional "I dont know" response option. Theoretical and empirical results have also shown that removing guesses (which produce Type-A order effects in 2AFC tasks) via the ternary format also prevents overestimation of the difference limen (DL).

The results just mentioned were obtained under the assumption that the decision boundaries are fixed across trials. Concerns have been recently raised about the possibility that decision criteria vary across trials.[2] This paper investigates the effect of such variations on estimates of the DL under the standard binary and the ternary response formats. For simplicity, results are reported for the case of a symmetric interval of uncertainty (i.e., $\delta_1 = -\delta_2$) and a single-presentation task, although results for 2AFC tasks were analogous and only included additional features from order effects. The indecision model with known parameter values was used to simulate data under two tasks: the standard binary task (in which undecided cases prompt guesses) and the ternary task that allows separate recording of undecided cases. Under each task, the decision boundaries were either fixed or varied across trials. The results show that variation in the decision boundaries across trials has little (and often negligible) effects on estimates of the DL under the ternary format, although they have large effects under the binary format. The robustness of DL estimates from the ternary format arises from the fact that undecided responses permit separating out the contaminating influence of the width of the interval of uncertainty.

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Theme session 5

Introduction: System identification in the psychophysical assessment of nociception

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Pain is shown to be a complex perceptual phenomenon emerging from neuronal activity in several neuronal parts of the so-called nociceptive system. A specific type of receptor, the nociceptor, codes for intensive thermal, mechanical or chemical stimuli which might be noxious, that is, potentially destroying tissue. Several characteristics of nociception and pain distinguish this perceptual system from other senses.

First, nociception and pain may arise from a set of versatile receptor classes assigned to small nerve-fibers operating in parallel and with different stimulus-response properties (e. g. A-delta and C-fibers). Second, these receptor systems can be positioned somewhere between the exteroceptive and interoceptive senses, because they are distributed not only on the body surface but also in large numbers within intestines, muscles and vascular systems of the whole body. Third, the principle of parallel processing is also found in the spinal transmission pathways, including a lateral and a medial system of nociception, named according to the target nuclei of the thalamus where these afferent signals converge. Fourth, there is no specific pain center in the brain, but several areas responsible for the different perceptual and behavioral aspects of perceived pain. Finally, pain perception is consequently described as a multidimensional phenomenon, comprising at the least sensory and affective, but also motivational components, introduced by the cerebral network of processing centers termed the "pain matrix".

It is therefore easy to conceive that the psychophysical assessment of pain perception bears a whole lot of complications that are introduced by the above mentioned special characteristics of peripheral and central stimulus processing. This is still aggravated by the consequences of malfunctioning in the nociceptive system, leading to sensitization, hyperalgesia, reduced habituation and/or endogenous analgesia. Neuronal plasticity is one of the core processes changing nociceptive transmission which might result in persistent pain syndromes and probably lead to chronic pain.

This starting point from neurophysiology will be presented in a short overview to give a comprehensible idea why systems theory and systems identification provide quite naturally a foundation for the basic research field of psychophysical pain assessment. This scenario implies, that systems theory and the methodology of system identification can provide an appropriate way to characterize the properties of the nociceptive system on several stages of processing, peripheral and centrally. This requires specific adaptations of classical psychophysical procedures, which have to be combined with the systems identification methodology. The aim of this session is therefore to elaborate on the idea of combining systems identification with psychophysical methods, and to present first examples for the expected rich avenues we hope would emerge from a combination of both methodological strategies. The contributors of this theme session hope that psychophysical research may take advantage from such ideas as well.

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On the road to system identification: Psychophysical assessment of nociceptive mechanisms

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Pain perception is a complex phenomenon which is constituted by a cascade of overlapping mechanisms located on processing stages leading from the peripheral nervous system on to the spinal cord, and finally to several areas of the brain. Psychophysical procedures based on experimental pain paradigms are currently used in clinical and basic research to specify the parameters of the mechanisms underlying pain perception. This mechanism oriented research fits the model of systems theory quite well, with circumscribed neuronal mechanisms representing subsystems in the processing line, each one characterized by its specific transfer function. The use of system identification methods in the assessment of pain processing depends on the methodology and specificity of the psychophysical procedures applied, to achieve a dissection of subsystem mechanisms and their parameterization. Three examples from pain research, applying contact heat pain stimuli, are presented to illustrate the specific problems related with that task:

Pain sensitization is a typical property in processing of repetitive phasic or tonic pain stimulation which has clinical validity as a feature of chronic pain syndromes [1]. The perceived stimulus intensity of such stimulus patterns increases over time, providing several measures of dynamic change in pain perception [2,3].

Supra-threshold sensitivity in processing of experimental pain is assessed in terms of stimulus response functions measured by magnitude estimation according to Stevens. The resulting functions are characterized by level and slope (Stevens coefficient) [2].

Endogenous analgesia elicited by tonic counter stimulation is a mechanism triggered by heterotopical nociceptive stimulation and counter-acting pain from another body site. There is a neuronal mechanism termed Diffuse Noxious Inhibitory Controls (DNIC) associated with it, which is well known from animal experiments. The study presented here illustrates the difficulties caused by the assessment of concurrent, and in consequence, confounded processes, like habituation, which cause an overlay in perception that has to be dissected from the mechanism of interest.

Finally, a proposal for a unified framework of psychophysical procedures and systems theory methodology is presented and illustrated by real and conceived examples from pain research.

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PaINSIGHT: Evaluation of nociceptive function from a system theory perspective

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The PaINSIGHT project aims at parameter identification of the nociceptive system for assessment of (mal)functioning during potential transition of acute pain into chronic pain states.

Activation of the nociceptive system, e. g., during surgical interventions, initially cause reversible nociceptive changes (modulation) in both ascending and descending pathways. Maladaptive modulation processes may prevent a proper return to baseline functionality and finally result in irreversible modifications of the nociceptive system: an often intractable chronic pain state. These initial modulations are clinically observed as hyperalgesia and measured using subjective pain reports and psychophysical testing, e. g. by determining electrical pain thresholds. However, such measures do not reveal the characteristics of the ascending and descending subsystems and their separate contribution to the hyperalgesia. This lack of specificity obstructs further research on the development, maintaining factors and potential therapies of chronic pain states.

The challenge is therefore to overcome the limited observability of present psychophysical threshold measurements and to permit a model based interpretation of improved measurements towards the neurophysiological function of the nociceptive subsystems. The strategy is based on experimental observations that electrical perception thresholds vary with the temporal characteristics of the stimuli (pulse width, number of pulses and inter-pulse interval). Series of thresholds from different stimulus properties reveal dynamic properties of peripheral activation and central processing mechanisms. When measured (tracked) during and after a nociceptive perturbation, such as a cold-pressor task, also the relatively slow effects of the descending inhibition can be studied. Furthermore, the effects of the stimulus properties on the threshold can be simulated by a simple nonlinear model consisting of two cascaded Wiener systems (4 parameters). Descending control can be modelled as slow changes in the model parameters.

The identification of the system parameters was initially based on a general nonlinear fitting procedure using experimentally estimated thresholds obtained with multiple stimulus properties. However, these thresholds are estimated from series of stimulus-response pairs. The challenge is therefore to develop an identification method which can deal more efficiently with the binary nature of this data, if possible by direct estimation of system parameters from series of stimulus-response pairs instead of estimated perception thresholds. The resulting identification method will provide insights for the design stimulus settings for clinical use.[1]

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Multiple thresholds tracking methods for improved observation of nociceptive function

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Estimating momentary perception thresholds cannot reveal dynamic properties of underlying mechanisms. However, continuously estimating (or tracking) a threshold over time can. A moving window including a number of most recent stimulus-response pairs allows this observation. While several psychophysical methods in the *yes-no* paradigm exist to obtain an estimate of the momentary threshold, obtaining its dynamic properties is not so common.

The possibility of tracking thresholds was demonstrated in simulations and a human subject experiment[1]. There, combining the simple staircase and the method of constant stimuli was proposed to use in experiments where thresholds are nonstationary. While tracking, it was possible to detect changes due to habituation as well as changes due to a conditioning stimulus. Extension of this tracking method is necessary to allow simultaneous tracking of multiple thresholds in order to identify nociceptive system specific parameters[2]. In preliminary results, we observed that estimation bandwidth decreases when more thresholds are tracked. Especially when large changes for a brief period of time are expected, as few as possible thresholds should be tracked.

Varying stimulus parameters (i. e., pulse-width (PW), number of pulses (NoP), and inter-pulse interval (IPI)) affect underlying mechanisms in different manners[2,3]. Therefore, in a study including healthy subjects, four thresholds were tracked (varying PW, NoP, and IPI) to observe the effect of stimulus parameters on thresholds. Moreover, two thresholds were tracked (1 vs. 2 pulses) before, during, and after a two minute cold pressor test. Preliminary analysis showed an effect of stimulus parameters as well as an effect of the cold pressor on thresholds.

Furthermore, a capsaicin defunctionalisation model was used to investigate its effect on four thresholds. A cutaneous capsaicin patch (8%) was applied to the upper leg in 8 healthy subjects. Thresholds were tracked on both the treated and adjacent untreated sites prior to application, and on subsequent days 2, 7, 28, and 84. Preliminary results showed that the effect of capsaicin was reflected in all thresholds, but was more sensitive on days 2 and 7 when using a one pulse stimulus, and more sensitive on days 7 and 28 when using two pulses.[7]

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System identification of the nociceptive function

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Pain is essential for survival but persistent pain reduces quality of life. One clinical symptom is hyperalgesia which results in either a decrease in threshold or an increase in suprathreshold response[1]. Hyperalgesia can be a consequence of peripheral and/or central sensitization. This perturbs the nociceptive system that is then malfunctioning. Our goal is to identify the nociceptive pathway and to characterize which parts are (mal)functioning. To this end, we adopt a system identification approach by integrating input–output measurements for estimating the parameters in a mathematical model of the ascending nociceptive pathway.

We consider data from a (binary) detection task with suitable variation in stimulus parameters. This is achieved by application of electrocutaneous stimulation using an intra-epidermal needle electrode. In each trial, current is delivered as a pulse train characterized by the amplitude and the temporal combination of the number of pulses, the inter-pulse interval and the pulse width. Then, the subject reports a binary response, perceived or not. From one trial to the next, the amplitude of the current is be adjusted using a staircase procedure[2]. The set of stimulus–response pairs (SRP) is the input-output data for our identification method.

In a previous study, we constructed a mathematical model of the ascending nociceptive pathway considering peripheral and central mechanisms. Analogous to the experimental paradigm, one can define the perception threshold (PT) for the model: the amplitude such that given the experimental temporal parameters and model parameters, half of the stimuli are detected[3]. The model reproduces PT variations similar as in experiments and depends on the parameters of the model. Based on this we were able to estimate the model parameters given the PTs. We found, however, that the addition of (measurement) noise in the PTs led to large estimation errors. Indeed, a relative error of only 0.1% in the PTs resulted in a 10% relative error in the estimation. We suspect this is due to losing information when transforming the SRP into a set of PTs. Therefore, we aim to improve the estimation by using SRP directly.

The staircase procedures can be formulated as Markov models[4]. This describes the eventual distribution of the amplitude of applied currents. For the staircase procedures we consider, the Markov models are ergodic, hence, a single realization or measurement is informative if the number of trials is large enough. Based on the final asymptotic distribution and the SRP, we formulate a maximum likelihood estimator for identification of the model parameters. We show that on simulated data this direct approach with SRP outperforms the indirect method with PTs. We study the effect of the number of trials and the choice of stimulus parameters,i.e., the pulse width and the inter-pulse interval, on the estimation performance.

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The evaluation of nociceptive function during early clinical drug development

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Pharmaceutical science continues to search for suitable biomarkers that can assist in predicting the therapeutic potential of analgesic medication and, therefore, its efficacy in the target population. Data intensive, early-phase studies provide a valuable opportunity that can offer this translational information. A series of nociceptive pain tests early in drug development could be used to bridge findings in the laboratory and those in the clinical situation, provide valuable information in regard to the mechanism of action of a new drug, predict the most applicable patient population to be studied, and ascertain the most relevant nociceptive test for more intensive pharmacokinetic/pharmacodynamic (PK/PD) modelling.

The need to use a comprehensive battery of pain models is highlighted by studies whereby only a single pain model, thought to relate to the clinical situation, demonstrates lack of efficacy. No single experimental model can replicate the complex nature of clinical pain. Therefore, one experimental pain model should not be used exclusively to screen the pharmacological mechanism of action of analgesic compounds. Data obtained from early phase clinical studies can be used to determine or confirm a drug's mechanism of action, which is especially true for drugs that are first-in-class. Furthermore, pharmacodynamic effects obtained from pain models may be useful for the prediction of the efficacy of the drug in future clinical populations.

Well-selected, multi-modal, validated nociceptive tests that each assess a different pain mechanism, should be able to help establish whether a drug is working centrally or peripherally, whether it is more suitable for a particular modality of pain (nociceptive, neuropathic or inflammatory), and what other effects contribute to its mode of action (sedation, tolerance, etc.). Furthermore, when used in combination with PK parameters, these nociceptive tests should be able to provide information regarding future dose selection. Particularly if used in combination with PK/PD modelling techniques, the establishment of the potential threshold for the pharmacological activity (thereby implying a therapeutic effect) may be determined and therefore used for dose prediction.

In this lecture several case examples are present and the human multi-modal pain test battery, and its suitability for early drug development, is discussed.

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Free talks 1

Perceptual processing of pairs of acoustically marked time intervals: Correspondence between psychophysical and electrophysiological data

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Event-related potentials (ERPs) elicited by pairs of subsequent time intervals marked by sound bursts were recorded in our previous study [1], and the data were reanalyzed utilizing a new multivariate method [2]. Subsequent time intervals t_1 and t_2 are often perceived as equal in duration when t_2 is shorter than 300 ms and up to 50 ms shorter or up to 80 ms longer than t_1 [3]; the subjective equality holds even if the physical difference is larger than the just noticeable difference obtained for t_1 and t_2 separated in time. This phenomenon is called *auditory temporal assimilation*. ERPs were registered in two types of sessions: J sessions, where the participants judged whether the two intervals were subjectively equal or not, and NJ sessions, where no judgments were required. Slow negative components occurred in brain activities in the J sessions, more conspicuous when inequality between t_1 and t_2 was perceived, in agreement with our earlier study [4].

An experiment in which t_2 was fixed at 200 ms was chosen for the present analysis. For a moving 100-ms time window, a correlation matrix across the 19 electrodes was calculated for each temporal pattern, and the correlation matrix distance (CMD = Euclidean distance between the respective correlation matrices) between each two patterns was evaluated. The patterns for which subjective equality dominated were classified as equal (E) patterns, those for which subjective inequality dominated as unequal (UE) patterns. There were four E patterns and three UE patterns, but no patterns to be classified otherwise. A measure of separation of E vs. UE patterns in terms of brain activities was calculated as the sum of squared CMDs between E and UE patterns, and expressed as *relative separation* (proportionally to the total squared CMD). The relative separation was a function of time, represented by the temporal midpoint of the moving window.

The relative separation in the J sessions showed a peak around 70 ms after t_2, similarly to our earlier findings [2]. A process related to E-UE judgment is thus likely to take place within 100 ms after t_2. Peaks within 100 ms after t_2 were observed also in the NJ sessions, suggesting that implicit judgments, although not required, may have occurred in a very early stage. The perceptual separation between the E and the UE patterns can thus be related to dynamic aspects of brain activities, critical factors of which we are trying to identify and locate. [5]

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Effects of elimination of power-fluctuation factors from critical-band noise-vocoded speech

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Sounds are divided into several frequency regions when going to a central auditory system from a peripheral system. This mechanism can be modeled as bandpass filters between which frequency ranges are different. These filters are called critical-band[1] filters.

Ueda *et al*.[2] reported that noise-vocoded speech[3] for which 20 critical-band filters were used was reasonably intelligible; 20 power fluctuations seemed to contain enough information for speech communication, and thus were subjected to factor analyses. Three factors appeared in a stable manner in eight different languages.

In the present study, we analyzed speech data of 3 languages (British English, Japanese, and Mandarin). The procedure of factor analysis was improved so that the factor scores should be zero when there was no sound, and this enabled us to resynthesize noise-vocoded speech based on newly obtained factor scores without systematic distortion. The 3 factors appeared corresponding to the previous studies, and accounted for 45.0–57.5 % of variances of 20 power fluctuations in these speech stimuli.

The roles of the factors in speech perception were investigated by measuring the intelligibility of noise-vocoded speech for which one of the factors was eliminated. Four Japanese-speaking participants (2 males and 2 females) listened to the resynthesized speech, of which the original was spoken by a Japanese male speaker, and wrote what they heard. Mora-identification ratios were obtained, and it turned out that elimination of any of the factors made the resynthesized speech less intelligible by 10–20 %. The differences in mora-identification ratio were small between the elimination conditions. No outstanding factor for speech perception was determined but it was suggested that the types of incorrect answers might be different between the conditions. Vowel errors were found often in the condition in which the factor located in a range of about 550–1800 Hz was eliminated.

We synthesized noise-vocoded speech, for which 10 filters of two critical-bandwidths were used. The speech was reasonably intelligible. We are going to perform factor analyses with these 10 bandpass filters. If power-fluctuation factors as in our previous studies are obtained, it will be possible to resynthesize speech from 3 or 4 fluctuating factors.

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Attention and working memory as determinants of identification thresholds for non-native speech sounds

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Linguistic experience attenuates adult listeners attention, desensitizing them to phonetic differences. The benefit is that within a listener's native linguistic environment, communication is facilitated by a reduction in the noise due to the association of several phonetic variants with a single phoneme. When language processing requires the use of non-native speech sounds listeners must allocate their attention to previously unattended features of the continuum. Evidence that listeners can successfully engage in psychophysical discrimination tasks using non-native linguistic distinctions and graded response time distributions along continua [1] suggests that acoustic properties are still available to listeners. How processing resources facilitate or inhibit the identification of native and non-native speech sounds has received limited attention. Studies that have used psychophysical training tasks [1] have proven effective in increasing participants sensitivity to regions along the acoustic continuum associated with non-native phonemes. We examine what factors affect listeners ability to attend to acoustic properties of the speech sounds.

In the present study, listeners were presented we the attentional networks test (ANT [2]) that uses a visuo-spatial flanker task to measure the efficacy of attentional networks of orientation, switching, and executive function as well as working memory tests that assessed reading span, visual span, and auditory span [3]. Following these tasks, listeners performed either a 2- or 3-category identification task with and without post-decisional confidence report. Subsequently, listeners were then requested to provide typicality ratings of the same stimuli. Identification accuracy, confidence reports, and typicality ratings were assessed conjointly to determine the extent to which listeners had subjective awareness of their own performance.

The main findings of the present study pertain to a three-way interaction between attention networks efficacy (ANE: high vs. low), working memory capacity (WMC: high vs. low), and whether listeners responded to a 2- or 3-category task, $F_{(1,50)} = 5.085, MSE = .77, p = .029, \eta_p^2 = .09$. The comparative low performance in the 3-category condition suggests that listener's native phonemes create interference during the processing of acoustic properties. Our results also suggest that attentional resources are used to process both acoustic and phonemic stimulus properties whereas working memory resources play the largest role in phonemic processing, especially when attentional resources are limited. Specifically, WMC was an important determinant of performance for participants with low ANE. Listeners in the high WMC group achieved a high level of performance in the 2-category condition whereas listeners with low WMC group performed worse in this condition relative to listeners who learned the non-native linguistic distinctions.

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Individual differences in auditory spectral temporal order judgments

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Auditory spectral temporal order judgments (TOJ) thresholds measure the ability to perceive the order of two tones of different frequency in a pair. Hirsh[1], and Hirsh and Sherrick[2] showed that the threshold for this task was 17 ms regardless of the stimuli characteristics, although later studies did not replicate their findings. In a series of studies carried out on 461 different participants we identified three patterns of response to spectral TOJ: very low thresholds (VLT, <5 ms, 50% of participants); mid-rage thresholds (MRT, 5–120 ms, 23% of participants), and very high thresholds (VHT, >120 ms, 27% of participants). We studied how these response patterns are affected by different parameters, as follows:

1. *Methodology and stimulus characteristics*. Short tone duration (5 ms) resulted in lower prevalence of VLTs (29%, $\chi^2_{(2)} = 11.768$, $p < .01$), while longer tone duration (40 ms) resulted in significantly higher prevalence of VLTs (75%, $\chi^2_{(2)} = 7.014$, $p < .05$). Using low frequency tones (300 and 600 Hz) resulted in higher prevalence of VLTs (88% of participants, $\chi^2_{(2)} = 4.833$, $p < .05$), while using high frequency tones (1 and 3.5 kHz) resulted in lower prevalence of the VLTs (29% of participants, $\chi^2_{(2)} = 11.786$, $p < .01$). Using adaptive or constant stimuli methods did not significantly affect the response patterns ($\chi^2_{(2)} = 0.145$ and 0.463, $p > .05$).

2. *Group differences*. Dyslexic readers had lower prevalence of VLTs (38%) and high prevalence of VHTs (46%, $\chi^2_{(2)} = 23.681$, $p < .001$). Aging adults had half of young adults' prevalence of VLTs (24%) and double prevalence of VHTs (55%, $\chi^2_{(2)} = 12.471$, $p < .01$). Interestingly, a group of 15 aging adults who currently engage in non-professional music activity had all VLTs. However, young adults with prior musical experience, but not currently engaged in musical activity, had the same thresholds distribution as found for the general sample.

3. *Cognitive ability*. Performance on digit span was comparable for all three threshold groups, but those with VHTs had lower score on WAIS-III matrices sub-test (mean = 12) as compared with VLT and MRT groups (mean = 14.41 and 14.50, respectively, $p < .05$).

4. *Auditory processing*. Mean hearing level did not differ between the three threshold groups, nor did thresholds in frequency discrimination, gap detection, duration discrimination, dichotic TOJ, inter-aural time differences, inter-aural level differences, and intensity discrimination tasks.

5. *Linguistic characteristics*. Speech perception of words and non-words in SNR of 0 and (−5) did not differ between threshold groups, nor was performance in speech perception with background speech noise, white noise, and 60% time-compressed speech. Reading non-words was significantly better for VLTs (mean = 69.86, as opposed to 60.50 and 63.67 for MRTs and VHTs). Accuracy in the Pig Latin task was lower for VHTs (mean = 3.92, as opposed to 5.17 and 5.50 for VLTs and MRTs).

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Free talks 2

Let's face it: Attempted incipient unification of differential geometric and dynamic concepts of facial expressions

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This study continues our program of representation of faces in terms of modern geometric and topological mathematics[1]. Before attempting a psychological and neurological taxonomy and theory, it would seem prudent to outline a reasonable mathematical framework for an idealized vision of the face-stimulus space. We will henceforth confine ourselves to that arena and drop continual reference to the "stimulus space". To that end, we propose the following:

I. Face space is an *uncountably infinite dimensional manifold* $\mathscr{M}$.

II. Gender related characteristics are embedded in $\mathscr{M}$ in such a way as there is a *smooth* transition from, say, more extreme masculine faces to the epicene, eventually to the extreme feminine faces. We view the "points" in $\mathscr{M}$ as containing all the geometric information about the physiognomy of the individual face but not skin tint, hair distribution, etc. Therefore, physiognomy information thought to relate to, say, ethnicity is retained.

III. Similar to (II), subspaces representing ethnicity "move" continuously into one another with no clear boundary. Mathematically (II) and (III) imply that the pertinent subspaces are open in the *F-topology*.

IV. Each face point in $\mathscr{M}$ is taken in Cartesian product with many other manifolds. Some of these are: A, Age; E, Emotional Expression; H, Hair style. Thus, we may designate the face *fibre bundle* related to $\mathscr{M}$ as the 4-tuple $F = [\mathscr{M}; \{A, E, H\}]$. Observe that our notation treats $\mathscr{M}$ differently than the other manifolds—this is primarily a convention.

Now, when discussing facial expressions, we adhere to the following: each face is viewed as a 2-D, connected and smooth manifold (i.e., a surface in 3-D). An expression is generated by a vector field on this manifold. Expressions from the Sender are evoked by the dynamics of a finite collection of muscle groups. The basic expressions are generated by a canonical set of specified muscle groups. Each basic expression is produced by a certain vector field which is associated with an infinite dimensional set of ordinary differential equations on the face-manifold. The Receiver is endowed, through years of learning, with a long-term memory of faces. We suspect that this memory is composed of, to a first approximation, an infinite dimensional vector space of all the faces ever seen. The magnitude of a face vector is a monotonic function of the number of times previously seen, attended to, and its novelty. Note that this construction need not assume that the addition or average of two faces is a face although that is possible. The system is noisy. The complete face space is a Cartesian product of faces, by contemporary gender, by emotional expression, and by age: $F \times G \times E \times A \times T$.

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Hyperbolic geometry of Ehrenstein–Orbison type illusions

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A large class of geometric-optical illusions (GOI) results from superposition of simple geometric figures ('target') with a pattern of other lines ('context'), due to which the target appears slightly distorted. In contrast to cognitive or neurophysiological theories of GOIs, our approach is based on a purely geometrical representation of the phenomena. In our earlier study [1] concerning Hering type illusions, the target element was a straight line. Here we deal with the case of a circular target, giving rise to phenomena (Fig. 1a) known as Ehrenstein or Orbison illusions.[2]

The idea is the same in both cases. We start from the observation that (segments of) straight lines and circles are *geodesics* (i. e., paths of shortest length between two points) in their respective 'base' geometries, namely, Euclidean and hyperbolic. The context is assumed to induce a slight perturbation of the base geometry, hence of the corresponding geodesics. A geodesic w. r. t. the perturbed geometry then serves as a 'prediction' for the actual, distorted percept of the target, τ.

The metric tensor, H_α, of the perturbed hyperbolic geometry depends on the context and on a real parameter α measuring strength of the distortion. An approximation of the form $\tau + \alpha\,\sigma$ is derived for geodesics in the H_α-geometry, where σ stands for the (computable!) shape of the perceived distortion, and α is to be determined experimentally. We use the method of compensatory measurement: the observer is presented a series of stimuli of the form $\tau - \alpha\,\sigma$ with varying α, and asked to select the one that appears most similar to a circle. As seen in Fig. 1, for some $\alpha > 0$ this adjustment removes the apparent deformation at the left-hand side of the circle (Fig. 1a) while maintaining the largely circular appearance elsewhere.

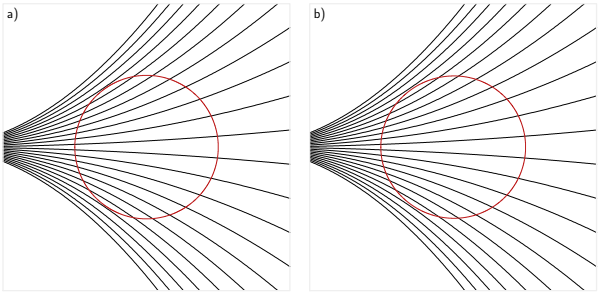

Figure 1. Perceptual distortions induced by an array of contextual curves: (a) Geometrically exact circle appears as an oval form; (b) counter-distorted ($\alpha = 0.02$) circle appears circular.

In a pilot experiment toward estimation of α, four different contexts were used, in the original position or rotated by 90°, two repetitions each (per subject). As a control condition, elliptic deformations of the target circle on a blank background (no context) were presented in five trials. The results obtained with eight subjects show a clear predominance of positive αs. There is no evidence for the existence of a general horizontal–vertical bias.

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Ultrametric Fechnerian Scaling

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Universal Fechnerian Scaling (UFS) is a principled approach to computing subjective distances among objects from their pairwise discrimination probabilities. It is based on the general concept of 'dissimilarity function' leading to a locally symmetric quasimetric in the context of Dissimilarity Cumulation (DC) theory developed by Dzhafarov and Colonius[1] and Dzhafarov[2,3].

For a finite set of objects, a 'dissimilarity' is a function that assigns to every pair of points a nonnegative number vanishing if and only if the two points are identical. A dissimilarity need not be symmetric and need not satisfy the triangle inequality. A dissimilarity satisfying the triangle inequality is called a *quasimetric*. A quasimetric G is induced by a dissimilarity D through the *dissimilarity cumulation* procedure: for each ordered pair of points (a,b), a dissimilarity $D(a,b)$ is replaced by the minimum of the sums of dissimilarity values across all finite chains of points from a to b. Dzhafarov[4] has shown that the procedure of computing quasimetric distances from dissimilarities can also be described in terms of a series of recursive corrections of the dissimilarity values for violations of the triangle inequality.

Here we show that the replacement of dissimilarity cumulation by a *dissimilarity maximization* procedure, i.e., replacing $D(a,b)$ by the minimum of the maximum value of the dissimilarities across all finite chains of points from a to b, results in a quasimetric satisfying the *quasi-ultrametric* inequality. In analogy to the triangle inequality, it can be shown that a series of recursive corrections on the dissimilarity values for violations of the ultrametric inequality yields the induced quasi-ultrametric distances, which is a basic requirement underlying many cluster-analytic procedures for embedding subjective distances in a hierarchical tree structure. Properties and limitations of this new procedure in the context of UFS have been discussed in Colonius and Dzhafarov[5]. Here applications of Ultrametric Fechnerian Scaling will be illustrated with empirical data sets.

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G.Th. Fechner: Correcting historical misrepresentations

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Fechner has been criticized for faulty mathematical derivations. This is misunderstanding, even if largely due to Fechner's own expository shortcomings. Fechner derives his logarithmic law in two ways, neither of which uses the notion of JNDs or Weber's Law in its traditional understanding. Instead they make use of the following postulate, which we will call "W-principle": *Subjective dissimilarity between stimuli with physical magnitudes a and b (provided $o \leq a \leq b$, where o is absolute threshold) is determined by the ratio of these magnitudes, b/a.* Fechner uses the term "Weber's Law" for both Weber's Law and the W-principle, creating thereby lasting confusion. Stated rigorously, the W-principle says that

$$D(a,b) = F(b/a), \tag{1}$$

where F is some function, and the subjective dissimilarity $D(a,b)$ has the properties of unidimensional distance: $D(a,b) = 0$ if and only if $a = b$; otherwise it is positive and $D(a,c) = D(a,b) + D(b,c)$. This additivity property is central for Fechner's theory, as he repeatedly states when discussing the notion of measurement.

Equation 1 implies

$$F(c/b) + F(b/a) = F(c/a). \tag{2}$$

By trivially transforming this equation into the Cauchy functional equation on positive reals, its only regular (in particular, nonnegative) solution is $D(a,b) = K \log \frac{b}{a}$, where K is a positive constant. Except for some unexplicated assumptions, this is Fechner's derivation presented in Ch. 17 of his *Elements*[1]. This very "modern-looking" derivation was overlooked by all Fechner's critics.

Ch. 16 of *Elements* contains another derivation, this one well-known but still misunderstood. It reduces Eq. 1 to a differential equation. Assuming that $F(x)$ is differentiable at $x = 1$,

$$D(a, a + \mathrm{d}a) = \mathrm{d}D(o,a) = K\frac{\mathrm{d}a}{a}, \tag{3}$$

where $K = F'(1)$. This is Fechner's *Fundamentalformel*, whose solution is the logarithmic function. The derivation is sound, the much-derided "expedient principle" mentioned by Fechner being merely his inept way of pointing at a trivially true property of differentiation.

If, in addition to the W-principle, Weber's Law happens to hold too, together they imply the "Fechner's postulate" $D(a,a') = const$, where a' is the stimulus just-noticeably greater than a. Fechner correctly tells us that if this constant is sufficiently small, then $D(a,b)$ is *approximately* proportional to the number of just-noticeable differences that fit between a and b.[2]

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Free talks 3

The circle of similarity

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Previous models of similarity rested on assumptions about the dimensionality of stimuli, the distance between stimuli, or non-metric relations among stimuli. In particular Ekman (1954) in "Dimensions of Color Vision" factor-analyzed similarity judgments of various wavelength pairs and extracted five factors to account for the results. Later Shepard, using a distance approach, needed only two dimensions to account for the results. In this presentation I will show how to account for the results without assuming any underlying psychological dimensions, and account for the similarities without estimating any parameters from the similarity measures.

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Who neglects base rate, perceivers or investigators: The effect of base rate on Stroop and Garner effects

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Stroop and Garner effects are psychology's classic measures of the selectivity of attention (indeed its failure) to a particular aspect of a multidimensional stimulus. Both effects have been shown sensitive to a wealth of contextual factors revealed by Algom and his colleagues[1–3]. In particular, the effect of color–word correlation has been the subject of much current research. However, virtually all Stroop and Garner studies to date employed equal base rates of colors and words, which may not reflect real-life probabilities. The neglect of base rate in Stroop and Garner research is all the more puzzling given its proved role in the expected likelihood of events and, consequently, on the pertinent behavior[4].

In a series of Stroop and Garner experiments with the dimensions of word and color and shape and color, we manipulated dimensional correlation and the marginal base rate of the various colors, words, or shapes. In the Stroop experiments, absolute reaction times (RT) remained invariant across different values of correlation and levels of base rate. Selective attention assayed the Stroop effect however did change: It increased with the number of congruent stimuli and uneven base rate favoring such stimuli. In sharp contrast, in the Garner experiments absolute RT changed as a function of correlation and base rate. Performance improved with dimensional correlation and the magnitude of imbalance in base rate. These results reveal the influence of base rate on speeded measures of selectivity.

The results further highlight the structural differences between Stroop and Garner measures. Finally, the results suggests the possibility of differences in the action of base rate when it is applied to non-speeded measures of prediction and its application to speeded measures, particular that of Stroop, which entails semantic relations between the tested dimensions.

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Is the flash-lag effect a special case of representational momentum?

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The represented position of a moving target is often displaced in the direction of motion. If the represented target position is assessed relative to the location of another (and usually briefly-presented) stimulus, this displacement is referred to as a *flash-lag effect* (FLE)[1], whereas if the represented target position is assessed relative to the actual target location, this displacement is referred to as *representational momentum* (RM)[2]. Surprisingly, there have been few direct comparisons of these two types of displacement[1,3,4].

Effects of several variables on the FLE and on RM are considered. Variables that have similar effects on the FLE and on RM include target velocity, visual field, presence of a landmark or reference point, target modality, presence of crossmodal information, attention and cueing, conceptual knowledge of target identity, control and movement planning, attributions regarding source of target motion, frame of reference, and potential neural mechanisms. Variables that have different effects on the FLE and on RM include oculomotor behavior, use of environmental- or object-centered coordinates, location of the target within the trajectory, level of processing, predictability of the target, and expertise of the observer.

The majority of variables that were considered had similar influences on the FLE and on RM, and this is consistent with a hypothesis of similar or overlapping mechanisms for the FLE and for RM. In cases in which a variable had different influences on the FLE and on RM, an account reconciling those data with a hypothesis of similar or overlapping mechanisms for the FLE and for RM could usually be suggested.

It is proposed that forward displacement of the moving target in the FLE and in RM results from similar or overlapping mechanisms. Indeed, the FLE might even be a special case of representational momentum in which location of the target is assessed relative to the location of another stimulus rather than relative to the actual target location. Such an explanation is preferred on grounds of parsimony: RM is simpler than the FLE (e.g., RM involves one stimulus and the FLE involves the relationship between two stimuli), and RM accounts for a wider range of findings than does the FLE (e.g., RM accounts for data involving a single stimulus as well as data involving the configuration of two stimuli). Such an explanation also suggests testable hypotheses regarding effects of variables studied for either, but not both, the FLE and RM.[3]

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Golden Section effects in visual cognition: A signature for complex-system organization?

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We reported[1] a series of experiments in which decision reaction-time (RT) to the shading (light or dark) of the smallest section of multi-sectioned displays was significantly slowed when the ratio between larger to smaller sections was equivalent to 1.61803..., a ratio also known as the Golden Section. However, we have failed to find any conclusive evidence from paired comparison tasks that Golden Sectioned displays are preferred over displays otherwise sectioned. Nevertheless we replicated the RT effects on several occasions and have found the effect to generalize to displays oriented 90° (to control for the possibility of visual field effects) as well as displays positioned further ways and closer to the experimental participants (which changed the retinal size of displays). Using a simulation of the circular on-off surround structure of neurons in the retina we analyzed the spatial frequency structure of our display matrices. Unlike all of the other ratios used (over the range 1.468–1.668) the Golden Sectioned displays failed to include any frequency components in the range ∼3–8° of visual angle. It might be that the additional time take to respond reflects an additional step in processing, such as feedback from later neurons coding global display structure to reinforce a weak bottom-up signal in visual and extra-striate visual cortex where neurons possess receptive fields of size 3–8°. To test this hypothesis, we added visual noise to each display matrix, convoluting the existing spatial frequency structure with a uniform distribution of visual signal across the displays. We reasoned this would be sufficient signal to activate neurons in all visual areas and would thus reduce the requirement for feedback and so reduce the extent to which RTs would be slowed to Golden Sectioned displays. Our findings confirmed this hypothesis. We deliberately used matrix areas in different ratios because area will be directly analogous to the numbers of neurons engaged, and synchronized into assemblies, and this relates to EEG work which has identified an absence of synchronization between assemblies synchronized at frequencies where the ratio of one to another frequency is the Golden Ratio[2]. This is strongly suggestive of a basis for Golden Sectioning in the dynamics of neural activity.

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Free talks 4

Spatial representations of numerical and non-numerical quantities in the auditory domain: Pitch and number

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Spatial associations of magnitudes with response sides exist throughout a broad variety of stimulus dimensions (e. g. length, numerical size, physical size, pitch height). The common underlying theory of this stimulus-response compatibility (SRC) states that small magnitudes are associated with left or lower responses while large magnitudes are associated with right or upper responses, resulting in higher speed and accuracy for compatible trials. These relations are assumed to be caused by linear representations of magnitudes, e. g. the SNARC effect for numbers[1] results of an internal mental number line on which numbers are ordered ascending from left to right. In contrast, the SPARC effect for pitch heights[2] is based on a vertical magnitude representation, i. e., pitch is ordered on a scale from low to high.

In the past, relations between dimensions have been investigated. A well-known example is the size congruity paradigm[3] that examines the interaction of physical and numerical size of single digits in the visual domain: When participants have to decide which is the numerically smaller or larger of two presented digits, responses are faster when physical and numerical size are congruent. Recent research[4] shows that this interaction takes place on the decision level ('shared decisions account') rather than on the representational level of stimulus processing: Congruity effects are only found when magnitude is relevant for the task. The authors predict that this account should also hold true for other domains that can be categorized in terms of magnitude.[4]

The present study investigated the relation between number and pitch in the auditory domain. Similarly to the size congruity effect in the visual domain, we expected faster responses when number magnitude and pitch height are congruent (e. g. a small number presented in low pitch). To test this, participants had to either perform a magnitude comparison or a parity judgment task on numbers sung in different pitch heights for a horizontal and a vertical response setting. While in the vertical setting congruency effects were indeed task dependent but reversed, our findings in the horizontal setting showed no congruency effect for both tasks, and the SPARC effect completely disappeared when numerical magnitude was not task relevant.

Our findings in the auditory domain with pitch and number show that the congruity effects predicted by the shared decisions account could not be replicated and were, if at all present, reversed. The dependency of pitch-to-space associations on task properties in the horizontal domain, however, goes in line with the assumption that the observed relation of pitch and number originates on the decision level of stimulus processing. Altogether our results support the view of a common underlying processing architecture of pitch height and number magnitude, but further research is needed to clarify the role of shared decisions.

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Measuring unconscious cognition without unconscious stimuli: Beyond the zero-awareness criterion

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I discuss two different lines of attack for establishing unconscious cognition. Traditionally, unconscious perception is demonstrated by simple dissociations between direct measures (*D*) of visual awareness and indirect measures (*I*) of processing *per se*; it is said to occur when *I* has some nonzero value while *D* is at chance level. In contrast, double dissociations occur when some experimental manipulation has opposite effects on *I* and *D*, for instance, increasing priming effects despite decreasing prime identification performance. I will show that double dissociations do not require unconscious stimuli to yield evidence for unconscious processing, and that they work under much weaker measurement assumptions than does the traditional zero-awareness criterion [1,2]. I will give examples of double dissociations from different research fields, including masked priming and lightness illusions.

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A psychophysical approach to early human development

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Viewing human development through the lens of psychophysical principles reveals a clear pattern and presents a new framework for observing, analyzing and developing human performance abilities. Utilizing our knowledge of planes of space, axis of motion, a center of mass, and the 'what' and 'where' streams of our motor, visual and auditory systems we can define psychophysical metrics for human development. A new theoretical approach to human development that incorporates psychophysical principles can enhance our ability to observe, analyze and engage human performance through each stage of development.

This new framework is built upon the simple premise that gravity profoundly affects the form and function of human performance. From how we move to how we learn, gravity determines the way we navigate data within our body field and our visual field. There is nothing we do apart from gravity. In fact, our bodies are equipped for data detection specifically as it relates to gravity via our vestibular system and 'where streams' in each neurosensory pathway. Without gravity the human form would not be symmetrical, sensory systems would not function properly and there would be no universal platform (figure ground) for data detection, collection or continuity. Gravity is the constant for the physics of movement as expressed through motion along and around the body axis. It is the constant of gravity that brings directional form to the symbols and objects we navigate within our visual field that give our world meaning and familiarity.

In the first year of life an average child masters control of *Z* axis function before becoming bipedal. A child learns to roll over (rotate), sit (balance) and crawl (translate) in the first year of life before developing the ability to control *Z* axis function in the vertical plane. All humans have the capacity to translate on an axis once becoming bipedal without being taught. Enhancing human performance by adding speed, flight and rotation require sophisticated coordination of body parts and higher order problem solving to be acquired with proficiency.

This presentation shows a correlation between how we observe and analyze movement with how we experience movement.

A psychophysical approach to early human development provides the opportunity to create new interventions, technologies and programs for engaging human performance ability during early development when intervention is most effective.

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The relational psychophysics paradigm: "Task switching" and data variability in comparative-developmental studies

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The relational psychophysics paradigm has been mainly used and discussed in the light of typical context-effect shifts. For instance, in previous research on the human's and animal's relational responding, several lawful transposition (*TP*) effects—i.e., context-dependent shifts—were found (mean data). Thereby, the comparative psychophysical data resulted from the application of a training and generalization-testing methodology with a two-alternative two-forced choice procedure (*2A2FC* task)[1,2]. Notably this paradigm implies the use of a "task switching" method, namely the immediate "switch" from the training phase to the testing phase thus resulting in highly variable test responses.

In this paper, the nature of the comparative-developmental data variability is analyzed as a task-switching phenomenon, thus taking into account the crucial inter- and intraindividual variability. This data variability was assessed from a reanalysis of several developmental studies with children as well as comparative investigations with chickens[3]. The results from these reanalyses are mainly based on the systematic comparison of a within- versus between-design methodology, with different human age groups and various infant-chicken groups tested for two psychophysical dimensions (size, color), with an eye on the individual variability. Thereby the chicken's inter- and intraindividual variability turned out to be drastically higher than that for the young children. Consequently, a data variability analysis rather than the typical mean-change approach was studied here.

The present findings are interpreted in the light of a task-switching memory-load hypothesis. Note that the human and animal subject's "surprise," due to the task switching from the training to the test phases, is assumed to be responsible for the noisy statistical data of the perceptual decisions needed for the respective *TP* findings. Naturally, the within-design data are much more variable ("noisy") than those resulting from the application of a between design methodology (cognitive-load hypothesis).[4]

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Free talks 5

Quantifying mental strain required to carry out everyday activities by German, Japanese and Canadian students

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The International Organization for Standardization (EN ISO 10075) defines mental stress as "the total of all assessable influences impinging upon humans from external sources…" compared to mental strain, which is defined as "the immediate effect of mental stress within the individual … depending on his/her individual habitual and actual preconditions…". While mental stress is usually being evaluated using physical measures, Bartenwerfer[1] proposed a category scale to evaluate the perceived psychological tension (in German "Psychische Anspannung") which is the phenomenal component of general central activation and as such an indicator for mental strain. In avoidance of unwanted context effects which might bias the given direct experience of strain, we adopted the Category Partitioning procedure (CP)[2] as the method of choice for the quantitative description of mental strain, expressed as degree of psychological tension associated with various everyday activities. The CP promises a valid quantitative representation of perceived states, if the related measurement instructions are considered[3].

In order to verify proposed translations for the German term "Psychische Anspannung" and to validate the suitability of the CP, students in Canada (CDN), Germany (D) and Japan (J), strictly following the related measuring instructions, quantified the degree of "psychische Anspannung" (D), resp. "sei-sin-te-ki kin-cho" (J) resp. "psychological tension" (CDN) which is required by 32 everyday situations, among them "watching the news in TV", "upon awaking, realizing that one has overslept" and "fixing a defective electric main while the wires are live".

Taking the small number of subjects into consideration the obtained correlation coefficients show almost perfect match between the data gained from students in Fukuoka, Vancouver and Lüneburg: $r_{(n=10\mathrm{CDN}/n=30\mathrm{D})} = 0.969$, $r_{(n=10\mathrm{CDN}/n=30\mathrm{J})} = 0.975$, $r_{(n=30\mathrm{D}/n=30\mathrm{J})} = 0.937$. These within an intercultural comparison obtained coefficients are in the order of comparisons between comparable studies in Germany: $r_{(n=18\mathrm{D}/n=30\mathrm{D})} = 0.989$ or a comparison between the female and male participants in the Japanese study: $r_{(n=12\mathrm{J,male}/n=18\mathrm{J,female})} = 0.994$, thereby confirming that the mental strain required by well known activities can be reliably measured across cultural borders. Beside of the general consensus the measured strain for a few single items may differ between nations. Japanese students experience higher strain while "getting stuck between two floors in an elevator at night" but they are more relaxed when "looking for the lottery ticket … thinking to have won $250" than their German and Canadian counterparts.

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Yrjö Reenpää and psychophysics

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Yrjö Reenpää (1894–1976), the late professor of physiology at Helsinki University, was one of the first in Finland to apply psychophysical methods in the research field of sensory physiology. Reenpää obtained his scientific methodology mostly from Germany. He regularly visited colleagues at German universities, among others in Berlin, Freiburg, Heidelberg, Leipzig, Würzburg, later also in Marburg (Herbert Hensel) and Erlangen (Wolf Dieter Keidel – visiting professorship in 1964).

Reenpää's own experimental research in psychophysics started with studies of the taste sense, and resulted in his academic dissertation in 1918. His further experimental studies concerned vision, proprioception and muscular sense (*Bewegungswahrnehmung*), as well as audition. He measured thresholds and discussed Weber–Fechner's and Stevens' laws as concepts for the phenomenal quantity.

As Reenpää very early realized that the psychophysical relation is basically an ontological and epistemological one, he applied Immanuel Kant's distinction between intuition (*Anschauung*) and concept (*Begriff*) to formulate phenomenology of sensory perception as the primary epistemological step. He also found ideas of Edmund Husserl, Martin Heidegger, and Hans-Georg Gadameri, of value for the interpretation of phenomenality in experimental observations, and for analyzing the nature of the psychophysical problem from an eidetic point of view. He laid emphasis on the sensory experience as the basis of all knowledge being given in noetic act of intuition, whereas conceptuality as such is a product of interpretation of the noematic content as experienced. He conceived phenomenality in terms of axioms, including axioms of simultaneity, quantity and independence, outlining the structure of the manifold of reduced sensory dimensions as a parallel to that of conceptual orthogonality. In addition, the axioms of discontinuity, and of lower and upper limits, characterize the primary sensory phenomenal space. Reenpää expounded his ideas in numerous publications, mostly in German language.[2–6]

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The 'alley problem': A neglected debate on size-distance invariance in XVII and XVIII centuries

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A special problem relative to the size–distance invariance is the so-called 'alley problem', which can be stated so: Looking from one end at a long alley having at the sides two parallel rows of trees, these don't appear parallel, but convergent. The problem consists in determining where one must posit the trees, in order that they look parallel instead.

The first to afford the problem was the Belgian Jesuit Aguillon[1] who stated that the trees had to stay along two opposite semi-hyperbolas. To demonstrate this, he showed that the trees had to stay along two curves, obtained intersecting the visual cone with a plane, and obtaining so the hyperbolas. The same was said by another Jesuit, Tacquet[2], who gave a similar (but a little clumsy) demonstration; and by a third Jesuit, Fabri[3] (with no demonstrations). According to Varignon[4] (again a Jesuit mathematician), which operated analytically, and not geometrically as the previous ones, the general curve was a hyperbola only in one particular case, and not correcting the data for the apparent distance of the trees. Doing so, however, we have a paradoxical result: the lines where to posit the trees appear convergent, and this is patently absurd. Later, Bouguer[5] showed that indeed Varignon had used in his demonstration the real distances, and not the apparent ones. To obtain the apparent distances, one must consider that the floor is perceived as positively inclined in the distance; Bouguer gave an experimental measure of the apparent slope, obtaining about 2° to 4°. Moreover, according to Bouguer the visual space appears as a sort of funnel, a half cone, with raised edges. With these corrections, we see that the trees must go along two divergent straight lines. D'Alembert[6] arrived at similar conclusions, but also gave a number of possible experimental suggestions. According to D'Alembert, who claimed his precedence on Bouguer, the experimental results of the latter must be checked carefully in several environmental conditions—but neither D'Alembert nor other researcher made such a control.

After D'Alembert, the problem was largely debated in the French mathematical world (by Montucla, Gergonne, Lehot, and others), till the beginnings of the XIX century, however without any new interesting result. Thereafter the issue was unfortunately completely forgotten, and this is a pity, because many problems today debated in psychology of perception (for instance, the problem of the so-called 'visually perceived eye level'[7]) could gain a deeper insight in the light of this old debate.

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The excursions of Galileo Galilei (1564–1642) into the moon illusion

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The moon illusion is the apparent enlargement of the sun or moon when near the horizon compared to higher in the sky. Many authors claimed that the image was optically enlarged by atmospheric refraction. Magnification does occur when looking from a thin to a dense atmosphere, but minification occurs when looking from a dense to a thin atmosphere. Several classical and medieval authors were aware of this, and suggested alternative explanations.[1] A popular perceptual account was based on size–distance invariance: the moon appears larger because it appears further away, and the brain scales the apparent size in proportion to the apparent distance.

Castelli[2] claimed that Galileo supported the size-distance invariance account. However, Galileo's published works mostly support some version of atmospheric refraction. Galileo published to that effect under the pseudonym of Mauri in 1606[3] and under his own name in 1610[4] and 1623[5]. The 1610 publication is interesting because, in addition to describing the egg-shaped moon illusion, he also describes the apparent enlargement of the moons of Jupiter by a factor of two or more. He later discussed the raising of the sun or moon above the horizon by atmospheric refraction: this occurs in a treatise mentioned in a letter in 1638, published posthumously[6]. There he suggested experiments on raising the sun's image above the horizon through different lengths of atmosphere, and measuring the time it took to sink below the horizon. He also noted that looking through the atmosphere was not the same as looking from air into water. He should therefore have known that atmospheric refraction could not cause enlargement. Perhaps he became aware of this, and refrained from writing about the moon illusion after 1623. He may have privately accepted the size–distance invariance account in his discussions with his pupil Castelli, which Castelli mentioned in 1639. It remains surprising that Galileo seems to have had little knowledge of the available literature on refraction and the moon illusion, at least until late in his career.

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Poster session 1

Separating predictive responses from reactive responses in isochronous finger tapping

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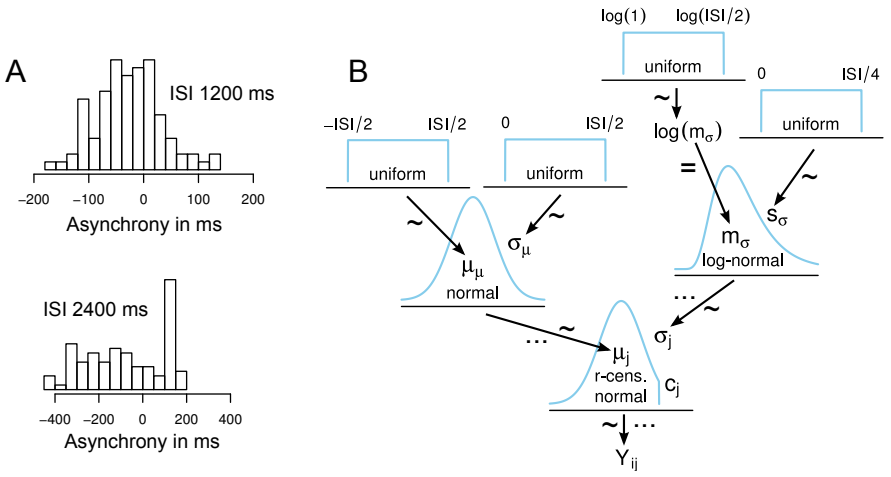
Finger tapping to isochronous pacing stimuli is a well established experimental paradigm where the basic measure is the time difference between a participant's *predictive* responses and the pacing stimuli, the stimulus-to-response asynchronies. Two parameters of common interest are timing variability and average offset from stimulus onset[1]. A difficulty when estimating these parameters is that at interstimulus intervals longer than 2 seconds participants regularly overshoot the target interval and instead react to the pacing stimulus. These *reactive* responses result in a left skewed, non-normal response distribution. See figure A for an example of the distribution of asychronies for one participant at short (1200 ms) and long (2400 ms) insterstimulus intervals. Using the sample mean and standard deviation to estimate timing variability and average offset is then not recommended as reactive responses may confound these estimates resulting in considerable negative bias.

A Bayesian hierarchical model was developed that models asychronies as coming from a right censored normal distribution. By setting the censoring limit, c, to 100 ms it is possible to separate the reactive responses from the predictive responses resulting in parameter estimates that are unbiased. After Kruschke[2], Figure B shows a diagram of the model where y_{ij} is the ith timed response from the jth participant. Comparing this model with classical moment estimators using both simulated and experimental data[3] shows that the Bayesian model estimates timing variability and average offset more accurately and with less bias compared to classical moment estimators.



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Octuplicate this interval!

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Stevens' direct psychophysical scaling methods[1] rest on the assumption that subjects are capable of processing ratios of sensation magnitudes. This assumption became empirically testable when Narens[2] stated necessary conditions of commutativity and multiplicativity to be satisfied by the data. Their validity can be tested by magnitude or ratio production experiments[3], in which the participant is instructed to adjust the magnitude of a comparison stimulus in a ratio p or q to the magnitude of the standard stimulus. The monotonicity axiom, which is even more fundamental, can be tested by determining whether presenting different numerals p produces corresponding ordered adjustments, i.e., whether representation of magnitudes occurs on a sensory continuum. If different successive ratio productions are commutative (i.e., exchanging their order does not affect the outcome), it can be assumed that the participant represents sensation magnitudes on a ratio scale. In addition, the multiplicativity axiom can be tested to show that successive ratio productions result in the same outcome as the single adjustments of their mathematical products. If the latter property holds, the participants use the numerals like scientific numbers.

To test whether these axioms hold for duration perception, $N = 10$ participants were asked to adjust the duration of a comparison tone to specific ratios of two different standard durations. In each trial, the standard interval (indicated by tones, presented via headphones) was followed by a comparison interval of random duration. The comparison interval had to be adjusted to a p multiple of the standard ($p \in \{1,2,3,4,6,8\}$). In addition, there were five types of successive adjustments (per standard), required for the commutativity and multiplicativity tests, in which participants had to extend a previously adjusted comparison interval (e.g., p times as long as the standard) by another ratio production factor q. Each participant produced twelve adjustments of each type, resulting in a total 264 of adjustments.

In line with previous findings obtained for other sensory continua such as area[4], pitch[5], or loudness[6], monotonicity held for the duration adjustments of all participants. Significant violations of commutativity were found in 12.5 % of all pertinent tests, whereas multiplicativity was violated in 32 % of the tests. These results demonstrate that participants are quite capable of processing duration on a ratio scale level, but that the numbers used to describe perceived duration cannot be taken at face value. Thus, the fundamental assumption of Stevens' direct scaling methods is of restricted validity for the perception of duration: even if a ratio scale of duration may be assumed, the overt responses cannot be interpreted as directly reflecting that internal scale.

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A fixed-links modeling approach to elucidate measurement impurity in reaction time data

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In traditional structural-equation modelling, a homogenous set of manifest variables are seen as equivalent indicators of the investigated latent variable. Performance measures obtained from cognitive tasks, however, may represent not only the concept of interest but can also be considered an outcome of various underlying processes and, thus, result in so-called impure measurements. To quantify and dissociate variance due to the concept of interest from variance from other processes, the fixed-links modelling approach was introduced [1]. For example, reaction time (RT) on tasks with increasing task complexity may involve common variance due to basic aspects of information processing as well as variance caused by the experimental manipulation of task complexity. In contrast to traditional structural-equation models, in fixed-links models, the links relating the latent variables to the manifest variables are fixed according to theoretical expectations.

In the present study, this approach was used to model data obtained by the Hick reaction-time paradigm. According to Hick's law, there is a linear increase in RT with the binary logarithm of the number of equally likely response alternatives [2]. Therefore, the average response time for one, two, and four response alternatives is expected to increase linearly. To separate variance due to experimental manipulation from common variance due to basic aspects of information processing by means of a fixed-links modelling approach, 130 participants performed a RT task with three levels of task complexity (one, two, and four response alternatives). Two independent sources of variance were modelled: (1) a constant process representing basic aspects of information processing unrelated to experimentally manipulated task complexity and (2) an experimental process increasing with task complexity. The representation of the constant process was fixed to equal unity for all conditions, whereas the shape of the experimental process was assumed to be strictly increasing with complexity. The Root Mean Square Error of Approximation (RMSEA) of a general linear increase, as predicted by Hick's law, did not fit the data well ($\chi^2 = 2.17$, $df=1$, $p=.140$, CFI = 0.99, TLI = 0.98, RMSEA = 0.098). Therefore, the fixations of the increasing factor were systematically altered until an excellent model fit was achieved ($\chi^2 = 0.00$, $df=1$, $p=.99$, CFI = 1, TLI = 1.02, RMSEA = 0.00). The fixations were 1, 1.52, and 2.92 for the increasing number of response alternatives (Fig. 1). These results challenge the implicit notion of a homogenous process underlying Hick's law. Furthermore, our findings indicate that fixed-links modelling provides a useful approach to solve the impurity problem.

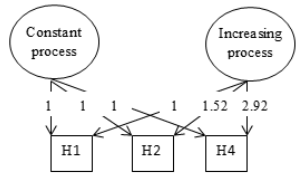

Figure 1. Fixed-links modelling of Hick data with two independent processes. H1, H2, H4 = Hick task with one, two, four alternatives.

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Effects of syntactic and semantic information in music composition on subjective perception of time

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It is well established that varied compositional elements of similar music excerpts can differently distort differently the subjective time estimation [1–3]. Syntactic and semantic elements of a piece of art are components which affect aesthetic appreciation [4]. This study aimed to examine the influence of syntactic and semantic properties of musical stimulus on time estimates, using excerpts from the piece 'Pictures at an Exhibition' by the Russian composer Modest Mussorgsky. The piece has metaphorical-descriptive free-form compositional sections (hereafter Paint-Music) inspired by some of Victor Hartmann's paintings followed by 'Promenade' sections which are structured upon a theme-and-variations form. It was proposed that these varied compositional elements of Promenades might exert different influences on time estimates. This study involved 180 Brazilian undergraduates of both genders, with no systematic study in music, aged from 18 to 35 years old. The participants ($n = 180$) were divided in three groups, each one related to one of three previous-to-stimulus verbal-instruction conditions: syntactic (SYN), semantic (SEM), and absent information (ABS). They were prospectively informed that the experiment implied a time estimation task. In a training phase, participants listened to the Promenade 1 preceded by a general SYN-, SEM-, or ABS-information concerning the whole piece. Immediately after Promenade 1 listening, participants were instructed to reproduce its duration using a computer keyboard. After that, the participants of each group were submitted to two trials, one with the presentation of Paint-Music 'Gnomus' followed by Promenade 2 and another of Paint-Music 'Bydlo' followed by Promenade 4. The order of trials was counterbalanced among the participants of each group. In each trial, participants received specific information corresponding to their group and music excerpt, listened to the Paint-Music, received instruction regarding the time reproduction task relative to the Promenade, listened to the Promenade, and reproduced the Promenade duration.

The preliminary analysis showed an effect of order presentation of 'Promenades' and thus the data analysis of this experimental phase was made considering only the first Promenade stimulus presented to each participant. The results showed that the time estimation of the group with syntactic information relative to Promenade 2 was shorter than the time estimation of the group with semantic information relative to Promenade 2. The results also showed that the time estimation of the group with syntactic information relative to Promenade 4 was shorter than the groups with semantic and absent information relative to Promenade 4. The results indicate that there was an influence of perceived cognitive aspects while listening to genuine musical excerpts on time perception. This influence can be mainly associated with the large scale musical cognitive (mode and tempo) and verbal (syntactic and semantic) aspects.

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Birds of a feather who flock together still don't assimilate

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Two types of hedonic context effects have been seen: assimilation and contrast. Assimilation is when the target stimulus becomes more hedonically similar to the context stimuli when it is judged in the context of those stimuli[1]. On the other hand, contrast is when the hedonic judgment of the target stimulus moves away from the context stimuli[2].

What determines whether assimilation or contrast is found? It has been suggested that assimilation occurs with simultaneous presentation of the context and target stimuli whereas contrast occurs with sequential presentation[1]. It has also been proposed that the mindset of the participant at the time of judgment can affect whether assimilation or contrast is seen[3]. Subjects primed to observe similarities will tend to show assimilation in their judgments, whereas subjects primed to observe differences will show contrast. One way to prime such similarities is to assign the context and target stimuli to the same category[4].

This study demonstrated contrast rather than assimilation using simultaneous presentation of two sets (finches and warblers) of three birds (one hedonically neutral bird flanked by two hedonically positive birds). Subjects in all groups were told that all of the stimuli they viewed were from the same category of stimuli (warblers or finches). In addition, three groups of subjects were given a task prior to giving hedonic judgments in which they looked for a similarity among the context and target stimuli (Group Similarity—a common characteristic) or differences (Group Rank—rank how much they like the 3 birds, and Group Favorite—pick their favorite). Another group (Group Context) was given no task prior to giving hedonic judgments and Group Control just saw and rated the target birds.

Mean attractiveness ratings of the target finch and warbler were computed for each subject in each group. A Kruskal–Wallis test comparing those means among the five groups was significant, $H_{(4)} = 13.9$, $p = .008$. Mann–Whitney tests comparing all of the groups found that all of the experimental groups rated the target birds as significantly less attractive than did the control group (all $p < .02$). No other differences were significant (all $p > .3$).

Although context and target birds were grouped within a category, simultaneous presentation of the target and context birds always resulted in contrast, never assimilation. This was true even for subjects who thought about how the birds are similar. This supports Fechner[5] who thought that both simultaneous and sequential presentation of stimuli produce hedonic contrast.

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Musical tonal modulation between minor keys and subjective time

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In Western traditional music, key is the compositional tonal environment induced by musical notes and chords, and it may be of major or minor types. Tonal modulation is the key change, that is, a development beginning at an original key, passing through a transitional section, and arriving at a destination key. The interkey distance is measured by the number of common notes shared between the two underlying musical scales of the involved keys: the lesser the note commonality, the longer the distance.

By using only major keys, Firmino and Bueno [1] presented four chord progressions unfolding close-sudden, distant-sudden, distant-gradual modulations, and a control no-modulation. Sudden and gradual modulations respectively refer to a few or many chords taken to modulate. Each participant listened to one progression and then retrospectively reproduced its duration using a computer keyboard. The authors found tonal modulations eliciting time estimations as an inverse function of interkey distances, with major impact for sudden modulations. In turn, the present study investigated the influence of tonal modulations between minor keys on time estimations with the same method of Firmino and Bueno [1]. The effects for minor-keys modulations were very similar to that for major-keys ones.

The stretching of the subjective time has been mainly explained by the amount or complexity of information [2], the demand of attention required by the stimulus and/or task [3], and the amount of contextual information surrounding stimulus and task [4]. However, such models do not confirm these data. Tonality and time are supposed to be acquired by implicit learning once both seem to be learned incidentally, by passive exposition, and through long-term. Such musical time knowledge fits the semantic memory concept stated by Schacter and Tulving [5]. The multi-component model for working memory by Baddeley [6] claims that information to be remembered must be rehearsed in order to prevent its decay and that any sound is verbally processed by the phonological loop component. However, both the present stimuli and responses are nonverbal.

Alternatively, Firmino and Bueno [1] proposed the Expected Development Fraction (EDF) model which can also explain the present data. It claims that if an interkey distance is traversed, an expected temporal development (in musical semantic memory) longer than the perceived duration (in musical implicit working memory) is evoked. Such disproportion or fraction is applied to perceived duration, leading to shortening of time.

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Object-based attention: A General Recognition Theory approach

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Observers are often more accurate when responding to two parts that belong to the same object, than when responding to two parts that belong to different objects[1]. This *same object advantage* is the hallmark of object-based research. It entails that objects are the elementary units of attentional selection. However, the internal representations that govern object selection are still not well understood.

The present work proposes a rigorous approach to modeling and testing object-based attention that relies on the concept of *perceptual independence*[2,3]. If object-based attention exists, then features from a single object should exhibit stronger dependencies than do features from two different objects. To test this idea, I employed the General Recognition Theory (GRT)[4] – a multidimensional elaboration of signal detection theory. The GRT affords the assessment of various forms of violations of independence and separability, and is capable of providing detailed descriptions of the underlying representation of multidimensional stimuli.

Four observers participated in the experiment. Stimuli were similar to those used in the classic study by Duncan[1], and consisted of a box and a bar superimposed over it. Two gaps appeared, either on the two sides of the box (i.e., within-object condition), or on the left side of the box and the bar (i.e., across-objects condition). Stimuli were presented briefly, and were followed by a masking pattern. Observers reported the location (bottom or top) of the two gaps.

Responses were summarized in identification confusion matrices. Of the four observers, two exhibited the *same object advantage*. To assess violations of perceptual independence, perceptual separability, and decisional separability, GRT tests were held. Consistent patterns obtained across all four observers. Sampling independence (SI), which is related to perceptual independence, failed in both within-object and across-objects conditions. Marginal Response Invariance (MRI), which is related to perceptual and decisional separability, held in both conditions. Macro signal detection analyzes, which are related to perceptual and decisional separability, held, showing equality of sensitivity (d') and response bias (c) parameters. The most likely interpretation of this outcome is that perceptual independence is violated and perceptual and decisional separability hold, with objects and non-objects alike!

Taken together, the results cast serious doubts on the validty of object-based attention: (a) when presented in close spatial proximity, features that belong to different objects are perceptually dependent, just like features that belong to the same object, (b) the internal representations underlying objects and non-objects are very similar, (c) the obtainment of *same object advantage* cannot distinguish objects from non objects in terms of their internal representation.

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Short-term learning effect in different psychoacoustic measures

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Studies which use psychoacoustic tasks differ in regard to stimuli properties and methods, but also in regard to the number of trials and blocks. Two previous studies showed a significant learning effect for spectral temporal order judgment (TOJ), but none for spatial TOJ[1,2]. The aim of the current study was to replicate and expand previous studies, using four psychoacoustic tasks. The expectations were (1) that improvement would occur from session one to session two, as a result of greater familiarity with the task and stimuli; and (2) that if these tasks require the participant to make different judgments, then also the effect of learning will be different.

Seventy-four participants performed either spectral TOJ ($N = 19$), dichotic TOJ ($N = 20$), gap detection ($N = 20$), or duration discrimination ($N = 15$). 1 kHz tones were used for all tasks, and an additional 1.8 kHz tone for the spectral task was used as the 'high' tone. Tone duration was 15 ms for the spectral and dichotic TOJ and 100 ms for the gap detection and duration discrimination tasks. Tones for all tasks were presented at 40 dB SL. All tasks were performed in a 2-forced choice 2-down-1-up adaptive procedure. Threshold was calculated for eight out of 10 reversals and represented ISI for spectral and spatial TOJ tasks, gap length for gap detection task, and duration delta between reference and target toned in the duration discrimination task. Each task was performed in two consecutive sessions.

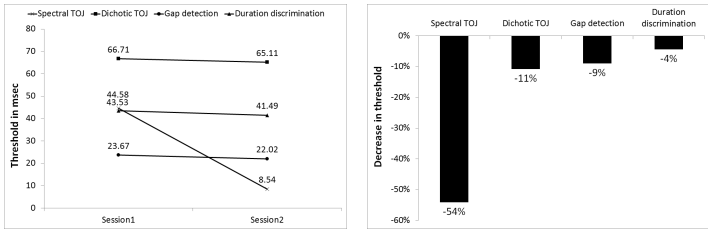

Figure 1. (a) Threshold in two consecutive sessions in four psychoacoustic tasks; (b) Percentage of threshold decrease in two consecutive sessions in four psychoacoustic tasks.

No threshold differences between first and second sessions were found in any of the tasks except for spectral TOJ ($t_{(18)} = 3.021, p < .01$, Fig. 1a). Mean percentage of change was significantly higher for spectral TOJ (54%) than for the other tasks ($F_{(3,73)} = 6.44, p < .01$, Fig. 1b).

Similar short-term training effect for three out of the four psychoacoustic tasks included in the current study suggests (1) that short-term training does not affect performance on most of psychoacoustic tasks; and (2) although different judgments are required for dichotic TOJ, gap detection, and duration discrimination, similar (non)training effect was found, suggesting shared perceptual mechanism. The results regarding spectral TOJ replicate previous studies[1,2] on substantial learning effect in this task. It also raise the possibility that the spectral information, which was included only in the spectral TOJ task, give rise to a different perceptual process than in the other tasks included in the current study, which did not involve any spectral information.

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A case study of time perception in the high level gymnast

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High level gymnasts realize bring into being defined points of space/time within parabolic tumbling arcs that when consistently attained assure the quality of the skill and also provide opportunities to initiate actions if needed to achieve a safe landing. Much as musicians use defined notes on a musical score to assure consistent quality of a performance, gymnasts use consistently placed, defined points of space/time (psychological moments) within the parabolic arc to achieve consistent quality of performance. The gymnast assesses not only body position (limb position to torso) but also orientation of the whole body to space (rotation by degrees in relation to the figure ground) at each point.

The number of space/time points brought into being appears to increase with the advancing level of the gymnast and the complexity of the skill performed. It also appears that complex skills can not even be attempted without these points and if points are lost or not attained it is an indication that serious errors and possibly catastrophic injury will occur.

Gymnasts seem to harness a type of fight or flight response into daily training in order to repeatedly practice high level (and dangerous) complex flipping and twisting maneuvers within parabolic arcs. After a gymnast has completed a skill within a parabolic tumbling arc it can take up to several minutes to explain all of the assessments, choices offered, actions initiated through each point in the arc to the final landing. In the explanation of one Olympic level gymnast who realized he snapped an Achilles tendon on a take-off, it took over 5 minutes to explain in detail every moment that passed in the 0.9 seconds of the parabolic tumbling arc to guide his body to a safe landing onto his back instead of his head or neck. These time perceptions seem to mirror those of individuals who experience fight or flight responses during car accidents when time seems to slow down and experience is magnified.

Gymnasts require consistent achievement of precise space/time measures required for a skill to be performed optimally. Their training is very much about defining, repeating and perfecting the psychophysical space/time interface to optimize performance and this requires a clarity and depth of time perception not commonly used in daily life.

A review of responses from a questionnaire given to world class gymnasts regarding space/time perception during parabolic arc maneuvers is presented in this poster.

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The filled duration illusion with the method of adjustment when filled vs. empty comparison intervals are used

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The duration between the onset and the offset of a continuous sound (filled interval) is often perceived to be longer than the duration between two successive brief sounds (empty interval) of the same physical duration. This phenomenon is sometimes called the filled duration illusion (FDI)[1,2].

In the present study, we examined the occurrence of the FDI with the method of adjustment, where the participants adjusted a comparison interval to match a standard interval of 100, 280, or 520 ms. There were four conditions regarding the types of the standard and the comparison (in this order), i.e. empty-filled, filled-filled, empty-empty, and filled-empty. In each condition, the point of subjective equality (PSE) for each standard was obtained, and the amount of the FDI was calculated by subtracting the PSE for the empty standards from the PSE of the filled standards with the same comparison type. We were interested in whether the FDI occurs in similar manners when the comparison was filled or empty.

The amounts of the FDI obtained from 41 participants, for each comparison type, were submitted to a cluster analysis. Results showed that, for both types of comparisons, participants could be divided clearly into two clusters: one without FDI and the other with clear FDI. The number of participants in the cluster without FDI (29 for filled comparison, 34 for empty comparison) was larger than that in the cluster with clear FDI (12 for filled comparison, 7 for empty comparison). This was consistent with our previous study[3]. There seemed to be no clear correlation in the amount of the FDI between the filled comparison and the empty comparison; the participants who showed clear FDI with one comparison type did not always show such large FDI with the other comparison type. It seemed that the FDI is not a stable phenomenon both across and within participants.

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Spatial compatibility in duration discrimination with manual and vocal responses

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Different types of information are sometimes processed by the same cognitive mechanisms; a classical example is that of number and space information processing. Although most studies on this research topic revealed this time–space interaction[1], there are still open questions regarding the cognitive processes involved. In particular is under debate the existence of a time–space interaction with characteristics similar to that of the number-space interaction: participants should be faster when responding to brief intervals with the left hand and to the long intervals with the right hand. Some experimental characteristics (e. g. use of manual responses) might impose a spatial representation, with effects on temporal judgments. If this is the case, we should eliminate the time–space interaction by asking participants to respond verbally, which is tested in the present study. Interestingly we used temporal accuracy rather than response time as dependent variable.

We compared participants' performance with vocal or manual responses in a time discrimination task where two pairs of visual stimuli (standard–comparison) were presented at the centre of the computer screen. Three ranges of durations were employed: short (400–1000 ms), middle (700–1300 ms) and long (1000–1600 ms); which were randomized within blocks of trials. The comparison durations were 25% shorter or longer than the standard. In Study 1, participants were instructed to judge if the second stimulus presented was longer or shorter than the standard by pressing one of two keys with the left or right index. Response keys were counterbalanced between participants with half participants assigned to a short–left and long–right condition, and half assigned to the reversed condition. With this procedure we could investigate the time–space interaction. We predicted better performances when the responses are short and associated with the left key, and better performances when responses are long and associated with the right key. In Study 2, participants were instructed to vocally give their response by saying aloud 'short' or 'long'.

In the case of manual responses, no effect of response key was found, indicating that the position of the response key was not affecting temporal performances. In both studies, a significant interaction between the standard duration and the duration of the comparison (short vs. long) was found, that can be considered as a time–time interaction. For short intervals, at 400 ms, better performance were observed when the comparison was shorter, while at 1000 ms, better performances were observed when the comparison was longer. Similarly, for middle durations at 700 ms, better performance were observed when the comparison was shorter, while at 1300 ms, better performances were observed when the comparison was longer. With long intervals, better performances were observed at 1600 ms when the comparison was longer. Our results suggest no time–space interaction and showed that the temporal performance is mainly related to the duration of the stimuli employed.

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Stand by your Stroop: The Stroop effect decreases in a standing position

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The vast majority of experiments in today's psychological science are done with the participant performing the task in a sitting position. Does performing the same task while standing make a difference? We argue that it does especially in view of theories of embodiment which recognize the influence of the motor system on cognitive responses. For example, approach and avoidance arm movements have shown to affect people's liking of objects and their reaction time to positive and negative stimuli. Notably, in a pair of recent studies Koch and her colleagues [1,2] have shown that locomotion is also associated with the mobilization of cognitive control. Movements of the entire body recruit control to a different degree. Thus, Koch *et al*.[1] found that stepping backward improved performance in the Stroop task compared with stepping forward.

Espousing Koch's insights, in the current study we moved a step further and hypothesized that performance in the Stroop task improves by merely standing rather than sitting. Participants performed in the classic color-word Stroop task, naming, while timed, the ink color of color words. One group performed in the customary sitting position, whereas another group performed while standing. For each participant we calculated the difference in color naming latency between congruent (e .g., the word RED in the ink color red) and incongruent (RED in green) stimuli (= the Stroop effect). The Stroop effect in the standing group was significantly smaller than that in the sitting group, documenting better selectivity of attention in the former position. These results are best understood within the framework of Koch's notions on resource recruitment. Mere standing up appears to be a powerful trigger of mobilizing cognitive resources. People do boost their ability to deal with conflict and difficult situations by standing up. Quite apart from the particular results of this research, we issue a call for the study of the psychology of standing.

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Context effects in estimates on objective scales: Scale distortion?

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Perceptual contrast is well-known and familiar in both the sensory and hedonic realms. It has been proposed[1] that a similar phenomenon might occur for the numbers that subjects use in rating scales. Frederick and Mochon's[1] Group RG (who estimated the weight of a raccoon in pounds before estimating the weight of a giraffe) gave lower giraffe weight estimates than did Group G (who estimated only the weight of a giraffe). (Group WG, who first estimated the weight of a whale, gave enlarged estimates of a giraffe's weight.) The authors attribute this assimilative effect to a contrastive process on numbers: RG subjects who estimated a raccoon's weight at (on average) "22 pounds" regarded big numbers like 1000 pounds as larger and to represent a larger weight than did G subjects who hadn't said "22 pounds".

In our severely underpowered replication, zebras and elephants (more giraffe-like in weight and habitat) replaced raccoons and whales. Group G subjects estimated the weight of a giraffe, Group ZG subjects first estimated the weight of a zebra and Group EG subjects first estimated the weight of an elephant. There were no significant differences among the three groups' estimates of a giraffe's weight ($p > .35$). EG subjects' estimates were highest (mimicking whale subjects[1]) but, surprisingly, ZG subjects' estimates were slightly *higher* than G subjects' estimates. The effect size separating our G vs. ZG subjects (Cohen's $d = -.06$) differed significantly from that separating Groups G vs. RG ($d = 0.5$)[1]. In a separate study, subjects who estimated the weight of "a dollar bill" (Group DG) in place of raccoons or zebras, also gave slightly higher estimates of giraffes' weights than did G subjects, again producing an effect size ($d = -.04$), significantly different from that separating Groups G vs. RG[1]. So there was no assimilation using zebras or dollar bills; similarity to the weight of a giraffe is not the issue. Our results did not differ from those on Groups G and WG[1] when Group AG subjects first estimated something much larger than a giraffe—an airplane.

Thus two studies modeled on the prior one[1] result in an asymmetry: "assimilative" data resembling the prior results when giraffes' weights are estimated after the weights of heavier things but not when giraffes' weights are estimated after the weights of lighter things.

It has newly been shown[2] that estimates of giraffes' weights are uninfluenced by prior estimation of the weight of a tricycle or an air conditioner. It seems that conceptual relevance is needed for anchoring effects to occur, consistent with the results of our study using dollar bills and airplanes. Scale distortion is an interesting idea that deserves further investigation.

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Assessing response times and peak force of responses to visual size and brightness

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Together with response time (RT) the force of responses to stimuli can provide important clues about perception–action links in the human brain.[1] In RT research, response latency is recorded from onset of a stimulus to a minimal force criterion sufficient to close a sensitive electronic switch. Response force (RF) and its time integrals are built up in the response over time, so it follows that RT is a direct function of force magnitude. Yet, response force (RF) continues beyond the minimum required for measurement of RT, so peak RFs can vary independently of RTs. Unlike RT, which is a criterion based measure, a different set of assumptions underlie assessment of peak RFs which are left implicitly to the discretion of participants.

The present work examines RTs and peak RFs to visual stimuli of increasing size and brightness. Each participant took part in two sessions. In one session operational feedback was provided by way of an auditory beep when the RF exceeded a minimum criterion (1.5 N), and reaction time recorded. In the other session no operational feedback was provided. The first 18 participants were not informed that the force of their responses was being measured; the remaining 18 participants were informed. An aim was to examine relations between visual brightness and size, RTs, and peak RFs, under typical, but otherwise uninvestigated, variations in experimental procedure.

In addition, the data were analysed using hierarchical Bayesian methods, which overcome problems associated with null hypothesis significance testing.[2] First, the overall effect of experimental instructions and operational feedback on RTs, and separately peak RFs, was examined by way of a split plot Bayesian analysis of variance. Second, relations between stimulus magnitude, RTs, and separately peak RFs, were examined by fitting $y = \alpha_1\,\theta_1 - \alpha_2\,\theta_2 + \beta$, where the variable y was the standardized log values of RT, and separately the standardized log values of peak RF, and θ_1 and θ_2 are the standardized log values of the luminance and area of the visual stimuli, respectively.

The results of our analyses indicate that operational feedback and force instructions certainly slowed RTs and reduced peak RFs, but provide no reason to believe there is any direct relation between visual magnitude and peak RFs. Yet, believable relations obtained between RTs and visual magnitude which remained constant throughout. In sum, the present work supports the view that assessment of RT, in terms of Piéron's function, with changes in visual size and brightness reflects the perceptual processing of stimulus magnitude.[3]

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Implicit coding of the temporal structure of events

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We explore the mechanisms involved in the sense of time continuity by examining how events are processed within temporal windows. Events within temporal windows are judged as simultaneous, and the overlap and hierarchical organization of successive temporal windows is usually supposed to underlie the sense of time continuity.[1] However, the concept of elementary time window is based on experiments in which subjects are explicitly instructed to decide whether two stimuli are simultaneous or not,[2] and our previous studies already suggested that asynchronous stimuli judged to be simultaneous are nonetheless distinguished in time. In the present work, we wanted to study these implicit abilities as directly as possible. To do so, we built a new test whose aims were to verify the hypothesis that successive events that occur within 'elementary time windows' are in fact distinguished in time; and to probe the time course of this coding and its content (motion or not).

Our first paradigm was aimed at testing whether or not there is an implicit coding of motion when two visual stimuli (primers) are presented in close succession. These primers were square frames displayed on the right and left side of the screen with an asynchrony of 17 ms. After a 100 ms delay, frames were subsequently filled in, and this filling-in represented the target information. Subjects had to decide on which side the last filling-in had occurred. Subjects were faster to response if the last filling-in was to the side of the first primer. These results are exactly the reverse of what was expected in case of motion coding. These results confirm that an implicit asynchrony has an effect on the judgment, independent of motion coding (but consistent with the prior effect[3]). However, we had to check if this implicit processing can be observed in a task that does not require a temporal judgment. We thus built Experiment 2 which was the same as Experiment 1 except that subjects had to detect a single target displayed to the side of one of the two primers. At a 25 ms delay, subjects were faster when the target appeared to the side of the first prime, whereas this performance advantage concerned the second prime side at a 100 ms delay.

Our data confirm that events are distinguished in time at an implicit level, independent of the task at hand; especially our results exclude the role of any visuo-motor or motion pathway activation. Moreover, the biases to the side of the second primer observed could be understood as automatic moves towards the most recent event, as if the visual system is wired to prioritize the last event. Since the asynchrony is unconscious, this might mean a permanent expectancy of the future moment, which might play a role in the emergence of the sense of time continuity.

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On the effect of nontemporal stimulus magnitude on perceived duration as assessed by the method of temporal reproduction

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Several studies suggest that perceived duration of visually presented stimuli increases with increasing stimulus size. To elucidate the nature of this effect, two experiments were performed using the method of temporal reproduction. In time psychophysics, performance on time perception is often explained by the assumption of a hypothetical internal-clock mechanism based on neural counting. According to this account, a neural pacemaker generates pulses, and the number of pulses relating to a physical time interval is recorded by an accumulator. Thus, the number of pulses counted during a given time interval is the internal representation of this interval. Based on these considerations, the effect of nontemporal stimulus magnitude on perceived duration should be brought about by a positive functional relationship between nontemporal stimulus magnitude and pacemaker speed. By employing a temporal reproduction task, the question of whether nontemporal stimulus magnitude affects pacemaker speed was investigated based on the following rationale: (1) If larger nontemporal stimulus magnitude speeds up the pacemaker rate, increasing the size of the stimulus marking the target interval should result in longer reproduced (perceived) duration. (2) If this assumption holds, increasing the size of the stimulus indicating the reproduction interval should result in shorter reproduced (perceived) duration due to increased pacemaker speed during temporal processing of the reproduction interval.

In order to investigate whether the effect of nontemporal stimulus magnitude on perceived duration can be explained by a direct effect on pacemaker speed, two experiments were conducted employing a temporal reproduction task. In Experiment 1, the effect of nontemporal stimulus magnitude on perceived duration was assessed by experimentally varying the physical size of the stimulus that marked target intervals ranging from 800 to 1200 ms, whereas, in Experiment 2, physical size of the stimulus marking the reproduction interval was varied. In Experiment 1, a statistically significant main effect of stimulus size on reproduced duration supported the notion that large target stimuli were perceived temporally longer than small target stimuli. However, there was no indication for a main effect of stimulus magnitude on perceived duration in Experiment 2 where physical size of the visual stimulus was systematically varied during the reproduction interval.

The present findings clearly argue against the general notion that the effect of nontemporal stimulus magnitude on perceived duration originates from a direct effect of stimulus size on pacemaker speed. An alternative interpretation implicates nontemporal cognitive processes to account for the effect of stimulus magnitude on perceived duration. When performing temporal reproductions, participants have to attend to the interval to be reproduced, maintain the temporal information, categorize it, make a decision, and, eventually, perform a response. Although not directly involved in the genuine timing process, all these operations are required for successful temporal reproduction. Thus, the effect of nontemporal stimulus magnitude on perceived duration may be mediated by one or several of these processes.

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Detecting and measuring auditory-cognitive interactions in speech comprehension

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Online comprehension of speech requires the smooth and rapid integration of a number of auditory and cognitive processes. The presence of competing sounds present challenges that are likely to slow or disrupt one or more of these processes. When such disruptions occur, it is likely that top-down compensatory mechanisms are engaged at different levels of the processing stream to insure comprehension of the targeted speech. However, the engagement of such mechanisms, and how this engagement might affect the different stages or levels of speech processing, is not easy to determine. In this poster we illustrate how judicious analyses of correlations between measures of cognitive competence and speech understanding (a procedure that is akin to an analysis of covariance) can be used to identify when and at what level compensatory mechanisms are engaged when listening becomes difficult due to the complexity of the auditory scene.

Imagine an auditory scene in which a listener is attempting to follow a conversation between two people in a quiet room, with one of the conversationalists situated to the left and the other to right of the listener. Now suppose we contrast this scene with one in which the same conversation is occurring in a room in which there is a connecting door to another room where a cocktail party is in progress. Under such circumstances, the source of the babble of voices from the cocktail party would appear to be located directly in front of the listener. The presence of the babble would be expected to interfere with the bottom-up processes leading to word recognition, thereby requiring the listener to focus her or his attention on segregating the two talkers from this babble of voices. In other words, attentional resources would be diverted to support stream segregation and word recognition, leaving fewer resources available for the execution of the kind of higher-order, more cognitive-level processing that supports, for example, theme extraction, the integration of information with world knowledge, and the storage of this information for later recall. The extent to which higher-order processes are engaged in such a situation could be assessed by examining the correlation between measures of general cognitive competence (e.g., vocabulary size, reading comprehension) and measures of speech comprehension in different listening environments. The greater the need for these higher-order cognitive abilities the more likely it is that individual differences in the measures of these abilities will predict individual differences in performance. If the task does not require a particular ability, or if either the quality or quantity of attentional resources is severely limited in a population (e.g., older adults) then we would not expect measures of this skill to be related to performance. In this poster we use this technique to show that top-down lexical processes are engaged only when there is reason to mistrust the information provided by bottom-up lexical processing of the conversation, and that some measures of higher-order cognitive processes, which are highly correlated with speech comprehension when listening is easy, may no longer be predictive of speech comprehension when listening is difficult. In general, it appears that the auditory and cognitive processes that are engaged in speech comprehension are modulated by a number of factors including but not limited to: 1) the complexity of the auditory scene, 2) the nature of the speech material, 3) the task demands placed on the individual, and 4) individual differences in the auditory, linguistic, and cognitive abilities of the listener.

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A fresh look at an old concept: Selective attention to aspects of a stimulus

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The ability to attend selectively to certain attributes of the environment while ignoring others is essential for adaptation and survival. One classic measure that tests the human ability of selective attention is Garner's speeded classification task. In his seminal work from 1978[1], Garner made a distinction between two major stimulus variables: dimensions, which have mutually exclusive positively defined levels, and features, which exist or do not exist in a given stimulus. With feature-generated stimuli, two stimuli types have a special role: the null stimulus, in which all features are absent, and the complete stimulus,in which all features are present. The feature-dimension distinction or, more precisely the difference between present–absent and present–present stimuli, has received sporadic attention in such diverse domains as similarity judgments[2], multiple cue decisions[3] and contingency judgments[4].

In the present study we took a fresh look at this distinction, taking advantage of the abilities of modern tools to measure reaction times individually for each stimulus type. We found a reduced ability to attend selectively, (i.e., more interference), for features generated stimuli, and no interference for stimuli that are generated from dimensions. In a second experiment we embedded this attributes in a richer social context using identity cards. Opposite to the results of the first experiment, we found a reduced ability to attend selectively for dimensions but not for features.

Our results can be explained by the distinct representation of features and dimensions in the stimulus space. This stimulus space is more elaborate in the dimensions-generated stimuli set, but more impoverished in features-generated stimuli set. Possible explanations for the context-sensitivity of selective attention as well as the special roles of the null and complete cells are also discussed.

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Visual cortex GABA predicts perceived duration

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Our perception of the duration of events constrains our experience of the world and exerts a pivotal influence over a myriad array of cognitive and motor functions. There is emerging evidence that the perceived duration of visual intervals is driven by the magnitude of stimulus-specific neuronal activity in sensory brain regions[1,2]. Endogenous constraints on this response may give rise to individual differences in interval timing. On the basis of these studies and independent research demonstrating that γ-aminobutyric acid (GABA) dampens visual processing[3], and its neural substrates[4], we hypothesized that elevated visual cortex GABA impairs the coding of particular visual stimuli, attenuating visual processing and producing a contraction of the perceived duration of visual intervals.

In this study, we tested the prediction that visual cortex GABA would be associated with the perceived underestimation of visual intervals. As a measure of visual interval timing, participants completed a duration discrimination task in which they judged sub-second visual stimuli of varying intervals relative to a constant standard interval. To ensure task specificity, we also administered a motor timing task in which participants reproduced the duration of empty intervals. We measured endogenous *in vivo* resting state GABA and glutamate concentrations in visual and motor cortices using magnetic resonance spectroscopy[5]. Duration discrimination data were fitted with a logistic function and the point of subjective equality was used as a measure of visual timing, whereas the mean deviation of reproduced durations from test intervals was used as a measure of motor timing in the duration reproduction task. We corroborated the internal replicability of correlations and compared correlations using bootstrap resampling.

Perceived duration of visual intervals selectively correlated with GABA, but not glutamate, concentrations in visual, but not motor, cortex, with elevated GABA associated with the perceived underestimation of visual intervals. Perceived duration was unrelated to motor cortex GABA and glutamate concentrations and duration reproduction performance did not covary with metabolite concentrations in either region. These results demonstrate anatomical, neurochemical, and task specificity and they are consistent with the hypothesized role of GABA in visual interval timing. Our findings bridge disparate results on the neuronal mechanisms underlying interval timing and the neurochemical basis of visual perception and provide further evidence for the role of local sensory-specific neural mechanisms in time perception[6]. The present results suggest that visual cortex GABA contributes to individual differences in the perceived duration of visual intervals.

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Factor analyses of power fluctuations in spoken sentences of eight languages: Analyses of individual data

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Three factors and four frequency bands were consistently observed through factor analyses of spoken sentences in eight languages, i.e., American English, British English, Cantonese, French, German, Japanese, Mandarin, and Spanish[1]. Group data of at least 10 speakers (NTT-AT, Multilingual speech database 2002) were used for each language. Generalizability of this tendency was confirmed in most cases from analyses of individual data. However, a certain range of variety appeared for a small number of speakers: some female speakers showed an irregular pattern of results with three factors, and some male speakers exhibited four factors in a stable manner. It led to the idea that speech with high fundamental frequency caused unstable results, and that speech with low fundamental frequency enabled four-factor solutions.

To test this idea, five sentences out of 200 in British English and five sentences out of 200 in Japanese were randomly selected, and fundamental frequency (F0) as a function of time was estimated for each speaker with Praat[2]. The voiced portions of utterances were selected on a computer screen, and fundamental frequency was estimated with autocorrelation. The female speakers of Japanese exhibited significantly higher F0s (mean $M = 248.6$ Hz) than those of British English ($M = 218.6$ Hz; $t_{(8)} = 3.27, p < .05$). The male speakers exhibited no significant difference ($M = 137.2$ Hz for the male speakers of Japanese; $M = 124.2$ Hz for the male speakers of British English). The three-factor analyses were successful in all female and male speakers, except for one female speaker of Japanese, who had the highest F0 of 276 Hz. No female speaker exhibited stable four-factor solutions, whereas some of male speakers did (4 speakers of British English and 3 speakers of Japanese). Three male speakers had higher mean F0s ranged from 149 to 155 Hz, and the four-factor solutions for these speakers were unstable. The speech with high fundamental frequency indeed led to unstable results, and that speech with low fundamental frequency led to stable results.

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Cultural modulations of space-time compatibility effects

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The representation of elapsing time may require spatial attention. In certain circumstances this spatial representation develops from left to right. This is suggested by a performance advantage in responding "short" with the left hand and "long" with the right hand (Spatial-Temporal Association between Response Codes, STEARC[1]). The present study tested whether one possible determinant of the directionality of the STEARC effect is cultural, similarly to what found with the SNARC effect[2]. In particular, we investigated whether reading/writing habits can affect STEARC direction by administering a visual time judgment task to Italian participants, who were exposed to a left-to-right reading/writing system, and Israeli participants, who mainly used a right-to-left system.

Participants were tested individually in a quiet and normally illuminated room. A trial started with the central cross, which remained on the screen for 1 or 3 seconds. These durations were presented randomly for an equal number of trials. After this period elapsed, the imperative arrow was shown. The task consisted of pressing 'Z' for a short cross duration (i.e., 1 second) and 'M' for a long cross duration (i.e., 3 seconds). We found that responses were faster for long durations than for short ones. Moreover, there was a tendency for a response side by duration interaction. Importantly, the response side by duration by group interaction was significant. To better understand this 3-way interaction, we ran an ANOVA with response side and duration as the within-subjects variables, separately for each group. This analysis showed a significant response side by duration interaction for the Italian group. However, as it has been found in other domains, the Israeli participants did not show any spatial response preference for either short or long duration, as demonstrated by a non-significant response side by duration interaction. Thus, the STEARC effect was present in the Italian group only.

The study demonstrates that cultural habits can influence the way in which spatial attention supports the representation of time, similarly to the pattern found in other non-spatial domains such as numbers. Future studies should try to test groups of individuals exclusively exposed to right-to-left reading/writing systems. The hypothesis that cultural habits are the critical factors biasing the spatial representation of time would be further confirmed if these individuals will show a STEARC effect which is significant and in the opposite direction with respect to that shown by individuals exclusively exposed to left-to-right systems.

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Anti-mirror neuron system model for affordance based *k*-TR Common Coding Theory

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Encoding of 'concrete nouns' such as 'cup' and 'book' in the human brain have been studied using fMRI. Breakthrough results by Just *et al.*[1] have shown that there is an underlying neuro-semantic theory to 'concrete noun' encoding. Rather than encoding by object sizes or colors, the brain encodes them by semantic categories such as (1) physical/ manipulation affordances (2) affordances corresponding to food consumption (3) affordance semantics, specifically localizer filtrations. These results are in line with predictions of the *k*-TR theory of visual perception which defines recognition as a composition of long-term affordance features and local transient features, as well as the Common Coding Theory which posits that visual and motor encoding is performed in the brain using a unified coding substrate. The regions that encode these physical/manipulation affordances are located at the Supramarginal Gyrus (language processing), Postcentral Gyrus (touch sensation), Precentral Gyrus (muscle movement) and Inferior Temporal Gyrus (global shape, complex features processing). The brain regions that encode affordance semantics are Precuneus (visuospatial processing), Inferior Temporal Gyrus (global shape affordances), Fusiform gyrus (material affordances like color and intra-category identification) and most importantly the Parahippocampal Gyrus – PHG (scene recognition), which has also been identified recently to be the center of anti-mirror neurons, along with the Entorhincal cortex, by Mukamel *et al.*[2] Anti-mirror neurons are neurons in the human subject brain that produce excitatory response when a certain affordance execution (such as grasping) is observed and a linguistic association is made in the form of entities involved in the affordance execution, but produce an inhibitory response when the affordance is executed by the subject. The PHG anti-mirror neurons also exhibit excitatory behavior when performing only linguistic association.

In this paper, we build a schema theory based on PHG anti-mirror neurons and the known affordance coding linkages (as noted above) of the PHG substrate, calling it the Anti-Mirror Neuron System (AMNS) and use it to explain various aspects of the *k*-TR Common Coding Theory. The various sub-schemas of AMNS such as the Object/Hand Perception Schema, Reach/ Grasp Schema, Core Anti-Mirror circuit along with the various biological units catering to the schemas in terms of sub-tasks such as object affordance extraction, motor execution, hand motion detection etc. and their contributions are analyzed through simulations and validated through psychophysical tests that involve subject recall of 'concrete nouns' based on observation of affordance executions with/without the target object, self-actuation without visual perception and solely based on touch and move-assist by an external agent, along with control tests and negative affordance coding linkages. These psychophysical tests demonstrate the contribution of various affordance features (observed/imagined, as well as both visual coding and touch/motor coding) with respect to object recognition or object identity label (concrete noun) association.

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Does perceived duration depend on physical and numerical stimulus magnitudes?

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Numerous studies provide evidence for a positive relationship between perceived duration and nontemporal stimulus magnitude. In the visual domain, perceived duration appears to lengthen with increasing nontemporal stimulus characteristics such as the physical size or the numerical value of a stimulus [1,2]. It remains unclear, however, whether physical size and numerical value can increase perceived duration in an additive manner. Moreover, the question whether such an effect depends on the participant's attention to those stimulus characteristics has not been explored yet. In order to concurrently investigate the effect of physical stimulus size and numerical value on perceived duration and, additionally, to examine whether such an effect depends on attention focussed to those particular stimulus characteristics, a temporal reproduction task was employed in the present study.

Thirty participants reproduced three target durations (800, 1000, and 1200 ms) marked by arabic numbers varying in physical size (large and small) and numerical value (low value: 2, 3; high value: 8, 9). Attention to particular stimulus characteristics was varied across two blocks. In one block, participants were instructed to also indicate, as a secondary task, whether the nontemporal target stimulus was physically large or small. In a second block, on the other hand, participants were required to indicate whether the target stimulus value was high or low as a secondary task. Mean reproduced durations were compared by means of a four-way analysis of variance with Target Duration, Physical Size, Numerical Value, and Attentional Focus as four repeated-measures factors. A significant main effect of stimulus size on perceived duration indicated that physically larger stimuli were perceived longer than smaller stimuli irrespective of their numerical value or participant's attentional focus. Beside a main effect of target duration (perceived duration increased with longer target intervals), no other main effect or interaction yielded statistical significance.

The present findings can be summarized as follows: (1) Our data provide further evidence for the notion of a positive relation between physical, nontemporal stimulus magnitude and percieved duration. (2) This effect seems not to depend on the participant's attention paid to particular stimulus characteristics. Thus, the processing of physical size appears to occur in an automatic way. (3) Our findings challenge the popular notion that larger numbers lead to longer perceived duration [1,2]. Since these latter studies employed the numbers 1 and 2 to represent low numerical stimulus values, the effect of numerical values on perceived duration might actually be caused by the distinct physical size of the number 1 and, thus, be ascribed to an effect of physical rather than numerical stimulus magnitude on perceived duration.

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Poster session 2

Static faces, dynamic bodies: The recognition of emotions in typically-developed individuals and high-functioning autistic adults

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Research on emotion recognition has been dominated by studies of photographs of facial expressions. Although during past decades there was a growing interest towards the role of facial movement in emotional expressions, results are controversial, given that it is very hard to separate experimentally the processing of facial identity from that of emotional expressions. This is particularly difficult in the case of dynamic displays. Besides, facial expressions are not the only source of input that conveys emotionally relevant information. In every-day situations, other sources—such as the communicator's body language or 'bodily kinematics'—are equally important, especially when facial expressions are inconsistent or unavailable to the observer. At a perceptual level, it has been demonstrated that biological motion (i.e., a point light motion display[1]) is sufficient for the perception of emotions. Thus, if on the one hand faces are universally recognized as the most important key element for understanding others' emotions, on the other hand a growing body of evidence shows that motion is also a core component of emotions.

The aim of the present study was to compare face and motion in the recognition of emotions, by excluding the motion component from faces and the facial identity component from body motion. To this end we compared performance (i.e., accuracy and response times) in the recognition of four basic emotions (fear, anger, sadness and happiness), conveyed either by static face images or by moving bodies. Emotion recognition was studied in 22 (21 males) typically developed individuals (TD) and in 20 (16 males, both groups mean age = 22 years) high functioning autistic young adults (mainly with Asperger syndrome, AS).

Emotional faces were taken from Radboud Faces Database[2], whereas for bodily kinematics patch light displays (PLD) were used, in which emotions were conveyed solely by biological motion, specifically by the kinematics of light patches placed on the joints of an actor[3]. The results showed an overall faster recognition of emotions when conveyed by faces, with a better performance for happiness and anger for face images in both groups ($p < .01$), and for PLD only in TD group ($p < .01$). Thus, in line with previous studies we found a happy face advantage and an anger superiority effect for faces, which for the first time were also found for bodies. As hypothesized, while the recognition of fear in TD was more accurate when it was conveyed by PLD, AS show an inverse pattern, with a more accurate recognition of fear when it was conveyed by static face images. In contrast, the recognition of sadness for TD was more accurate when it was conveyed by static face images, while in AS it was equal with static face images and PLD. Interestingly, however, in AS recognition performance with PLD was not modulated by the different emotions.

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How well does the Wong–Baker FACES scale identify the variation of pain?

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Pain is one of the most common symtoms reported clinically. Apart from the Visual Analogue scale, several rating scales are used varying in degree of interpretability and suitability for various types of pain[1]. One scale often used, especially for children, is the Wong–Baker FACES Pain Rating Scale where pain is expressed in six drawn faces varying in expression from (1) a smiling face denoting 'no hurt' to (6) a crying face for 'hurts worst'[2].

Two experiments were carried out. Firstly, 12 university professors of psychology (8 men and 4 women, 50–79 yrs) answered where (in what face) they judged that pain with certainty started. Three answered that pain started in the sixth face. Two said that no face showed pain and the rest said that the dimension shown was degree of happiness-sadness. However, if the intensity of pain was estimated as if using cross-modality matching (sadness to pain), three said face no. 4, one no. 4-5, one no. 4,5, or 6, and two said face number 5 (median = 4.5).

Secondly, sixteen university students (4 men and 12 women, mean age = 27.2, SD = 7.4 yrs) answered the same question as above and then also used the Borg CR100 (centiMax) Scale®, a general 0—100 intensity Category-Ratio scale for most kinds of subjective measurement[3], to scale the pain intensity expressed in each of the six faces (presented twice in a randomized order in a Powerpoint presentation). Pain was 'with certainty' judged to start at the fifth face, and several participants scaled the first two faces as 'zero pain'. A continuous progression of pain intensity for the six faces was on the average obtained with the CR100 scale: medians = 0.0, 0.5, 11, 31, 48, 72 centiMax. Thus, expressed with the verbal labels on the CR100 scale, the first two faces were below 'Minimal', which indicates that these faces were not judged to show any pain, the third face was just above 'Weak' (13), the fourth face just above 'Moderate' (25), the 5th face just below 'Strong' (50) and the 6th face was just below 'Very strong' (70).

The conclusion was that the faces only with hesitation can be used to estimate pain. The last face was not judged to show more than a very strong pain, thus causing a restriction of range and a ceiling effect. A problem with these kinds of scales is poor congruence between pictures, verbal labels and numbers.

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Perception of blackness as a training material for the Borg CR100 Scale®

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The Borg CR100 Scale® is a general intensity scale suitable for most kinds of experiences and symptoms. On the scale verbal labels are placed in congruence with a ratio scale from 0 (nothing at all) to 100 ("Maximal" and anchored in a previously experienced perception of, for example, perceived exertion), with, for example, "Strong" at 50 and with the possibility to exceed 100 in extreme situations[1]. For instruction and training the blackness of 5×5 cm cardboard squares (varying from 5 % to 95 % blackness NCS[2]) have previously been used with an exponent in the psychophysical power function of between 0.9 and 1.2 (obtained both for Magnitude estimation and previous versions of Borg CR scales)[3]. For practical reasons it is important to be able to use a Powerpoint presentation of blackness stimuli, for example when running classroom experiments. Two different randomized orders of 18 (2×9) blackness stimuli were presented in a classroom setting to 47 participants (16 men and 31 women, students of psychology). Microsoft Powerpoint for Apple was used with the 9 different greys preset in the program (5, 15, 25, 35, 50, 65, 75, 85, 95 % blackness) and scaled with the Borg CR100® Scale. Two orders of presentation were used, the second being the reverse of the first.

The responses obtained with the Borg CR100 scale® ranged from 2 to 90 (median values) showing that blackness worked well across the whole subjective dynamic range. This is of importance for a good training material. The group exponent, computed from geometric means, was $n = 1.3$ ($r = 0.994$) and thus a little higher than previously obtained. For a subgroup of 14 subjects who were retested after approximately 15 minutes the exponent for both occasions was $n = 1.1$ ($r = 0.985$ and $r = 0.965$, respectively). From graphs it was obvious that there was a slight "dip" with relatively lower responses for 35 %, 50 % and 65 % blackness, especially for the first presentation order. This might in part explain why the exponent was a little higher than obtained with the older cardboard presentations. Whether this "dip" was mainly due to design, the blackness stimuli, or the scale, remains to be tested. However, as a training material, this would have less consequence. As a conclusion, a Powerpoint presentation of blackness works well, and may be recommended as a training material for the Borg CR100 scale®.

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A Functional Measurement approach to the Child Anxiety and Pain Face Scale

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The CAPS[1] is a set of two face scales, composed of 5 drawn faces each, for assessing pain intensity and anxiety in children. In the present study we evaluated the claim that the two sets of faces actually address distinct constructs. To this end, we examined the rules whereby the inner features of each subset of faces are combined by children while evaluating conveyed pain or conveyed anxiety/fear.

The study rested upon the methodology of Information Integration Theory[2]. Faces in each set were divided into upper- and lower halves (grossly, 'eyes/eyebrows' and 'nose/mouth' regions), which were then fully factorially combined, giving rise to 25 'pain faces' and 25 'anxiety faces'. Two samples of children (aged 9–11) participated in the experiments: a pain-free group, ($n = 23$); an acute-pain group, undergoing a post-operatory experience ($n = 21$). Pain and anxiety faces were evaluated in different experiments. Each experiment obeyed a 5 (upper-face) $\times$ 5 (lower-face) repeated measures design. Children were asked to evaluate on a graphic rating scale the degree of expressed fear (anxiety experiment) and of expressed pain (pain experiment). Both experiments were replicated with a sample of pain-free children ($n = 19$) using reversed instructions (pain judged from 'anxiety faces', and fear from the 'pain faces').

Parallel plots and a null interaction term were found with the 'anxiety faces' in both groups. Rightward convergence of the factorial plots and a significant interaction term were found in turn with the 'pain faces'. These results are consistent with an additive-type integration model in the anxiety set and a differential-weighting averaging model in the pain set. Functional measures of weight (importance) derived from the averaging models revealed that 'eyes-eyebrows' in the pain set, and 'mouth-nose' in the anxiety set, got the most importance, a finding established in both groups. Reversing the judgment dimension in each set didn't change the integration rule or the characteristic patterning of relative importance of the faces features.

Outcomes thus lend support to the construct validity of the CAPS, showing both distinct psychological rules for the combination of informers in each set, as well as a symmetrical pattern of relative importance between eyes and mouth. The graphical/pictorial elements of the two sets, and not the judgment dimension, are to be accounted for these differences, which remained unaltered despite a reversal of instructions.

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Losing ground: The perception of height as a function of the makeup of the ground beneath

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Perception and emotion have been considered separate domains of human experience with little interaction in everyday life and research alike. However, recent studies have revealed deep associations, suggesting that the process of perception is not immune to the effects of emotional and motivational factors such as mood, perceived risks and goals, and resources required for the task at hand[1]. Even low level visual processes can be influenced by the perceivers emotional state. For example, fear can change the apparent height of a balcony such that people with an elevated fear of height experience the height of a balcony to be greater than do people who are not as fearful of height[2,3].

In the current experiment, we tested the effect of risk on perceived height. The participants were standing on the same bridge with either grass or concrete pavement beneath. They indicated the height of the bridge by numerical estimation. The participants have also fit the length of a rope to match the diameter of a circle on the ground. Finally, the participants filled a short situation anxiety questionnaire. The results revealed that those who looked down on the solid pavement perceived the height of the bridge to be significantly greater than those who looked down on the soft lawn. Fear of height did not affect the judgments of the height. A surprising finding was the negative correlation between fear of height and the perceived diameter of the circle on the ground.

The results of the current experiment reinforce the bond between risk and the way that people perceive height. The participants likely perceived the lawn as less hazardous then the hard pavement, with judgment of height reflecting (unconsciously?) this perception. The results support embodiment theory by which emotions provide information on the consequences, costs and benefits, of potential actions.

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Effects of contrast and background on visual representational momentum

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Representational momentum for luminance in a target that changed in luminance has been investigated[1], but representational momentum for location in a target that changed in luminance, and effects of contrast of target luminance and background luminance on representational momentum for location, have not been systematically investigated (although one report suggested forward displacement was larger for targets that decreased in luminance on a dark backround[2]). In Exps. 1 and 2, inducing stimuli implied leftward or rightward target motion, and target luminance and contrast varied. In Exp. 1, participants judged whether a probe was at the final location of the target. In Exp. 2, participants judged whether a probe was at the next location that would have been occupied by the target if motion had continued.

In Exps. 1 and 2, the target on each trial was either (a) high contrast (dark gray on a white background, light gray on a black background), (b) increasing contrast (from light gray to dark gray on a white background, from dark gray to light gray on a black background), (c) decreasing contrast (from dark gray to light gray on a white background, from light gray to dark gray on a black background), or (d) low contrast (light gray on a white background, dark gray on a dark background). The probe was the same luminance as the final luminance of the target.

In Exp. 1, forward displacement was larger with higher contrast of the target and background. High or increasing contrast targets exhibited the same final (high) contrast, and displacement did not differ in these conditions; low or decreasing contrast targets exhibited the same final (low) contrast, and displacement did not differ in these conditions, but was less than forward displacement in high or increasing contrast conditions. Effects of contrast involved final, rather than initial or mean, contrast. Forward displacement was larger if targets were on a white background, and effects of contrast were larger if targets were on a black background. In Exp. 2, significant displacement did not occur, nor was there an effect of contrast; however, there was a trend toward backward displacement if targets were on a white background.

Larger forward displacement with higher contrast in Exp. 1 is consistent with findings that forward displacement is increased if less attention is allocated to the target[3]. Lack of displacement in Exp. 2 is not consistent with suggestions that displacement reflects explicit prediction of where the next inducing stimulus would appear[2].

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Maintenance of the distractive effect of deviating vibrotactile stimuli in a cross-modal oddball paradigm

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It is well-known that certain properties of unattended information can capture attention: for instance, sounds deviating (called deviant sounds) from a repeated standard sound (i.e., the oddball paradigm). However, attention capture comes with the cost on the behavioral performance in an ongoing task. Response times increase in a primary task in trials in which a deviant sound is presented (i.e., behavioral deviance distraction)[1,2]. Past studies were focusing mainly on attention capture by auditory deviants[1,2], somewhat less on visual deviants[3] or tactile deviants[4,5].

As for the tactile modality, a pilot study from our lab found that the distractive effect of deviating vibrotactile stimuli disappeared after the first block of 120 trials. An earlier study from our lab found that the deviance distraction by sudden changes in vibratory stimulation remained throughout the experiment. However, in that study auditory and vibrotactile blocks of 3 minutes duration were alternated[5]. Thus, it was clear that the distractive effect of vibrotactile stimuli could be maintained if another task lasting 3 minutes was introduced between vibrotactile blocks. The aim of the present study was to test if 3 minute pauses between vibration blocks would be sufficient to maintain the distractive effect of vibrotactile stimuli or if, as previously seen, another task between blocks was necessary for maintenance.

The present study used a cross-modal oddball paradigm and a hand-held vibrotactile stimulator, 20 participants categorized visually presented digits as odd or even while ignoring vibrotactile or auditory distractors, which were presented prior onset of each digit. Blocks containing a standard vibration (80 %) and a deviating vibration (20 %) were alternated with 2 blocks containing auditory stimuli or 2 pauses of 3 minute duration. The order of the blocks were counterbalanced. It was found that the distractive effect of deviating vibrotactile stimuli was maintained with the introduction of pauses, regardless as to whether the pause was filled with a attentionally demanding task or not ($P < .05$). Furthermore, no significant difference in deviance distraction was found whether the vibrotactile blocks was preceded by a pause that was attentionally demanding or not ($P > .05$).

In conclusion, introducing a 3-minute pause is as effective as using an attentionally demanding task for the maintenance of behavioral deviance distraction in the vibrotactile modality.

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Motion extrapolation in people with motor constraints: Evidence for embodiment

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Previous studies have suggested that people with cerebral palsy (CP) are impaired in their motor planning abilities[1] and present a slow-down of motor imagery (MI)[2] – with MI generally defined as the inner reproduction of an action while motor output is inhibited[3]. Performance on tasks involving dynamic mental representations[4], such as Representational Momentum or Motion Extrapolation (the estimated time at which a moving target will reach a location), have on the other hand been suggested to rely on mental imagery.[5,6] This study compared CP and control participants using a Time-To-Contact paradigm (TTC) which requires estimating the time at which a target in motion makes contact to an obstacle in the frontal plane.

48 CP participants (7–56 yrs) and 48 age-matched controls were enrolled in the experiments. Included CP participants didn't have a record of cognitive deficits or parietal injury and performed at a normal level on an adapted handedness test. Stimuli were videos of a blue square (1 cm side) moving horizontally at a constant speed towards a stationary obstacle, and disappearing at a given point. Obstacles of two sorts were used, block-wise: (1) a black human silhouette; (2) a black vertical rectangle matched for area and contrast. The direction, speed and vanishing point of the target were varied, along with the position of the obstacle, resulting in a 3 (speed) $\times$ 8 (distance between the target's vanishing point and the obstacle) $\times$ 2 (direction) design. Participants pressed a button to signal the moment at which the vanished target would make contact to the obstacle.

Anticipation (underestimation of the time to contact) in both groups was larger in the silhouette than in the rectangle condition. Participants with CP anticipated more than controls but more so in the silhouette condition, disclosing a significant effect of the type of obstacle. Anticipation in the CP group increased with the degree of functional impairment, from ataxic, to diplegic, to quadriplegic participants. The magnitude of anticipation correlated significantly with a measure of gross motor function impairment (the GMFCS), involving the whole body (0.37). No relation was found between the degree of anticipation and questionnaire measures of visual and motor imagery (KVIQ). Our results thus seem consistent with the use of an embodied 'threshold of anticipation', more strongly activated in the silhouette condition and dependent on overall motor constraints, rather than with the use of mental imagery for a predictive motion extrapolation.

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Representational momentum in people with cerebral palsy: Effects of response format and delay imposed on the response

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Cerebral Palsy (CP) is a developmental disorder of movement and posture[1]. People with CP have shown ability to perform mental imagery tasks (e.g. mental rotations), however at a slower pace than controls[2]. We investigated whether similar limitations would show up in a Representational Momentum (RepMom) task, assumed to involve dynamic representations[3]. RepMom refers to the forward mislocalization of the vanishing point of a moving target by observers, an error denoted hereafter by the more neutral expression M-displacement[4]. O-displacement will stand for the error orthogonal to motion direction.

48 participants with CP and 49 age-matched controls participated in two experiments. Stimuli were videos of a blue square (1 cm side) moving horizontally on a white background at a constant speed, and suddenly vanishing. A 4 (distance travelled by the target) $\times$ 3 (target's velocity) $\times$ 5 (delay imposed to the response, from 0 to 750 ms) design was used. In one experiment participants located the vanishing point by displacing a mouse or trackball (motor localization). In the other they issued a same/different judgment regarding the placement of a square which could be located behind, ahead, or at the position where the target had vanished (probe method).

Participants with CP displayed more M-displacement in the motor localization condition but less M-displacement than controls in the probe condition. In the localization condition, the magnitude of M-displacement increased with the severity of functional impairment as assessed by the Gross Motor Function Scale (GMFCS) and the Manual Ability Classification Scale (MACS). A significant positive correlation emerged between M- and O-displacement (downward localization error), which also correlated positively with hands functional impairment (MACS). A negative correlation (-0.746) occurred between M-displacement and a questionnaire measure of motor imagery. In the probe condition, M-displacement peaked at longer delays in the CP group (around 600 ms, compared to 150 ms for the controls). Our results illustrate a clear effect of motor constraints on the dynamic representations assumed to underlie RepMom. The lower magnitude and late peaking of M-displacement in the CP group in the probe condition are overall consistent with a slowing down of mental imagery. The observed increase in both M- and O-displacements with functional impairment in the localization condition is suggested to rest on embodied motor anticipatory mechanisms, likely involved in the planning of actions towards moving objects.

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Measurements of distinguishing abilities of clothed buttocks

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False accusations have been serious problems in groper cases. Does a victim have enough tactile ability to distinguish a gropers hands from other objects? This study was conducted to examine tactile distinction ability; for example, do clothed buttocks have the ability to distinguish between hands and bags?

In an experiment a female experimenter touched the buttocks of three male and three female participants with her hands or a bag, and distinguishing abilities between the stimuli were measured using the two-alternative forced-choice technique. At the experiment the male participants wore jeans and the female participants wore pleated skirts.

As the experimental results showed no significant difference between males and females, the average results were calculated and are shown in Figure 1. The ratios of correct responses were 0.547 between the right hand and left hand, 0.669 between the palm and the dorsum side of hand, 0.764 between the open hand and the fist, 0.817 between the open hand and a bag, and 0.744 between the fist and the bag.

Differences between the ratios were checked by t-tests (all tests with 11 d.f.). Differences at the 0.1 % level were found between the RH, LH and the OH, F ($t = 6.476$), between the RH, LH and the OH, B ($t = 6.552$), and between the P, DH and the OH, B ($t = 4.504$). Differences at the 1 % level were found between the RH, LH and the F, B ($t = 4.258$), and between the OH, B and the F, B ($t = 3.398$). Differences at the 5 % level were found between the RH, LH and the P, DH ($t = 2.762$), between the P, DH and the OH, F ($t = 2.237$), and between the P, DH and the F, B ($t = 2.215$). No significant differences were found between the OH, F and the OH, B, and between OH, F and the F, B.

In conclusion, the distinguishing between the right hand and the left hand was impossible. The distinction rate between the palm and the dorsum of the hand was 2/3. The distinction rates between the open hand and the fist and between the fist and the bag were 3/4. The distinction rate between the open hand and the bag was 4/5. Statistical differences were found between the distinction ratios in many cases.

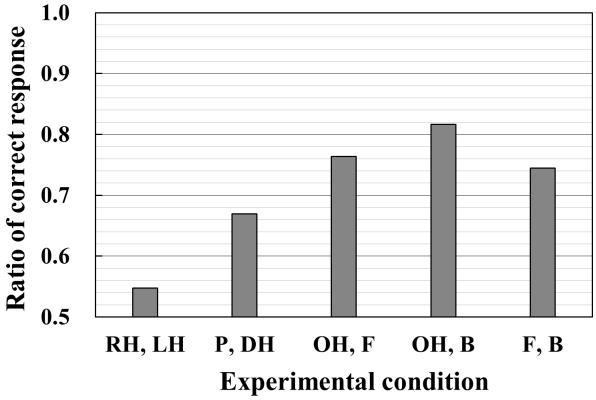

Figure 1. Abbreviations: RH – right hand, LH – left hand, P – palm, DH – dorsum side of the hand, OH – open hand, F – fist, B – bag.

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Intermediate effects of spatial training on women's Mental Rotations Test scores

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Measured gender differences in cognitive abilities appear to have diminished over time[1], but mental rotation continues to yields large, statistically differences favoring men. A meta-analysis[2] of spatial ability studies found a linear increase in effect size with age suggesting that gender differences in spatial ability may be affected by experience, sexual differentiation, or both. The largest gender difference was found with the Mental Rotations Test (MRT).[3]

In addition to the biological differences between women and men, there are experiential differences between genders[4], such as early childhood toy preference and play[2]. For example, puzzles are completed by mentally or physically rotating pieces to make comparisons. Dolls and board games do not emphasize spatial relationships and may be less likely to influence spatial ability. Voyer *et al*.[2] found that men and women who reported childhood preference for spatial toys performed better on the MRT than those who preferred non-spatial toys. Nevertheless, men's performance was greater overall.

The practiced group consisted of 44 women who completed six sessions of practice with figures different from those in subsequent testing. The women's and men's control groups consisted of 53 and 40 participants. Members of all three groups took the Revised Mental Rotations Test[5] (RMRT) consisting of items from the MRT plus an additional four items. The figures of each item were presented in rectangular boxes instead of ovals. Practiced women scored 55 % higher than did control group women. Practiced women's and control group men's scores were not significantly different. Twenty-two practiced and 16 control group women were again tested on the RMRT 4.5 months later. With the smaller, self-selected groups, practiced women scored 34 % higher on the first test and 26 % higher on the second test than control group women. Neither group scored significantly higher on the second test than the first test. Neither group improved their score significantly.

The results seem to indicate that memory for RMRT items fades, at least in women, after a few months but that skill improvement is maintained. Complicating factors in that conclusion include not only the smaller self-selected samples for the second test, but also the fact that there was no significant correlation between Test 1 and Test 2 scores for either group. Nevertheless, that on the average, women maintained their improved scores after a third of a year seems to indicate that the effect of practicing with figures similar to but different from the test's figures confers a somewhat lasting, improved ability to complete the RMRT. Practice improved women's spatial ability, via RMRT scores, to a level not significantly different than unpracticed men's.

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Metric effects of taking tears out of the Wong–Baker Faces Pain scale

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Whether or not to employ anchoring elements such as smiles and tears in pain faces scales for pediatric use is a controversial matter. While the effects of smiling faces as lower anchors have been shown to result mostly in higher pain scores[1], little is known about the effects of using tears in the higher anchors[2]. In this work we use Information Integration Theory[3] to study the effects of removing tears of the higher anchor of the Wong–Baker Faces Pain scale (WBFPRS)[4].

Two groups of children (aged 9–10 years) evaluated 36 pairs of faces arising from the factorial combination of the 6 faces of the WBFPRS with the 6 faces of the Facial Pain Scale-Revised (FPS-R)[5]. Tears were removed from the higher anchoring face of the WBFPRS in one of the groups ($n = 17$; $n = 26$ in the remaining group). When presented with each pair, children were made to rate the degree of conveyed overall pain on a horizontal (600 pixels wide) graphic rating scale.

In accordance with previous studies[6], children used a differential weighting averaging rule to integrate the two pain informers, which allowed for independently estimating scale values and functional importance for each face. Only the fifth face of the WBFPRS had its scale value significantly altered by the removal of tears: previously indistinguishable from face 4, it became virtually indistinguishable from the higher anchor face. No significant effect on the range of the WBFPRS (difference between the higher and the lower faces scale values) was found. Overall, the WBFPRS became perceptually closer to the equal interval ideal. Measures of importance disclosed a noticeable reduction in the importance accorded to the higher anchoring face, which became similar to that of the other faces. As a provisional implication, it is suggested that wiping out tears in the higher anchor face of the WBFPRS may help improving scale linearity (an actively sought after metric property) and homogenizing the psychological importance accorded to faces (susceptible, for instance, to pain-associated affect) with no loss in the overall range or in the degree of discrimination between faces in the scale.

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Extracting salient perceptual features of machinery noise using triadic comparisons

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Triadic comparisons have been proposed as an indirect method for identifying perceptual structures [1], i. e., the hierarchy of auditory attributes emerging from a given set of sounds. Compared to alternative methods it has the advantage that it disconnects the identification of auditory sensations from their labeling. While the technique has been applied to simple synthetic sounds and to the spatial auditory reproduction of music [2], an applicaton to industrial product sound has been lacking. Therefore, the present work investigated the auditory features of sounds emitted by gear units.

The present study selected six recordings of industrial gear units, each running in stationary mode and lasting 5 s, which are of different types and further differ in load and rotational speed. Each of 15 normal-hearing participants completed a full triadic comparison, consisting of 60 trials. In addition, ten participants repeated the procedure in a second block and, in a third block, were presented with all questions which had differed between the first and second block.

Compared to an earlier study using simple synthetic sounds [1], the present work employing actual recordings of a more complex nature resulted in a greater number of response changes between blocks. Furthermore, none of the ten subjects was free of transitivity violations when combining the three blocks, which had been the case for almost half of the participants in the earlier study [1]. Thus it is only possible to represent the individual feature structures (by constructing lattice graphs) if some answers causing the transitivity violations are changed. Doing so for up to a maximum of 10 percent of the trials, unique lattice graphs could be constructed for seven of the fifteen participants.

As a result, remarkable individual differences were observed: The seven participants generated a total of 18 nodes, with only three of the nodes being shared by at least half of the participants. Each node represents (at least) one feature which the stimuli belonging to this node have in common but other stimuli do not have. Both the individual representations, and the nodes common to the sample as a whole were further characterized using two strategies: First by relating them to the outcome of a scaling study of the same sounds performed earlier [3], and second by computing objective psychoacoustical metrics of the sounds.

The lattice graph representing the three nodes being shared by the majority of participants could be labeled with the traditional psychoacoustic parameters of loudness, annoyance and tonality, but also some additional more domain-specific descriptors such as ‘droning’, ‘grinding’ or ‘whining’ may be identified. The attribute ‘droning’ could even explain all three nodes. The technical-constructive properties of the machinery, by contrast, e. g. load and rotational speed, did not help to describe the listeners’ perceptual space.

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The centrality of psychophysics to psychology: A Hephaestian paradigm

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A peculiarity exists within experimental psychology: if psychophysical methods are foundational, why is so little reference made to them within the psychological literature? I will consider the extent to which this phenomena represents paradigm change [1] and reformulation of the boundary of disciplines of psychology [2]. A bibliometric analysis provides evidence that the methods and object of study of psychophysics represent a core of modern experimental psychology's Wundtian paradigm. Disciplinary reformulation is therefore considered to be the most plausible basis for the relative absence of reference to Fechner in particular and psychophysics more generally.

Like many practitioners of early psychological science, Fechner's interdisciplinary interests had considerable breadth: medicine, evolution, aesthetics, physiology, and philosophy. This gives Fechner the appearance of modern day cognitive scientists which makes reduced references to him in the literature relative to other early practitioners such as Wundt and Helmholtz somewhat puzzling. Methods developed and codified by Fechner in his work provide the basis for much contemporary research. Moreover, thresholds and discriminative accuracy still remain the core of much contemporary experimental psychology in numerous research areas. Citation analyses of English and German corpora suggest that this is partially the result of the Americanization of psychological research with a concomitant shift to regional priorities.

In order to understand why Fechnerian psychology might be reject we must consider its theoretical and metatheoretical underpinnings. Unlike contemporary psychology's dominant materialist focus, Fechner's *panpsychism* characterized all matter as mind. A rejection of the metatheoretical foundations leaves only the mathematical foundations of psychophysics: amongst them the emblematic Weber–Fechner fraction. Here it is important to note the a-theoretical parallels with behaviourism and the contemporary paradigm's rejection of the behaviourist's 'blackbox'. Moreover, the formation of the development of the modern paradigm brought with it a wariness of 'the cult of empiricism', a growing emphasis of theorizing in publications, and a reduced emphasis on individuals offering results in the absence of theory. The comparative lack of concern with these internal operations relative to the modern paradigm are likely to have play a similar role in the absence of reference to early psychophysics (similar accounts of Fechner's work are provided in the context of psychoaesthetics [3]). Given the similar citation patterns for Hermann Ebbinghaus and Johannes Müller, it seems more plausible that the pre-paradigmatic nature of this work is the most likely explanation for the comparatively reduced level of citation of Weber and Fechner.

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Computational modeling of correct responses proportion among confident ones in ‘greater–lesser’ task

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Two years ago a mathematical model has been developed [1] which described an ideal observer’s choice of the most correct or the most useful response and his (her) estimation of confidence in this response. The model reveals effects of erroneous responses payoffs and correct ones costs on mean expectable all-alternative utility and confident responses correctness probability in ‘greater–lesser’ task (see Figure 1). If payoff is less than cost, then all observers’ responses are confident. When payoff is greater than cost, then unconfident responses appear. The model predicts that along with the payoff further increase a number of unconfident responses increases, a number of confident ones decreases, but a proportion of correct responses among confident ones permanently increases. So, this proportion is always greater than proportion of correct responses in the whole data sample.

The model supposes: a) ‘post decisional confidence’ to be a subjective indicator of a chosen response preference regarded to a rejected alternative; b) ‘decisional confidence’ to be a subjective indicator that the chosen alternative exceeds a minimal utility level demanded, as well; c) if no alternative response exceeds the minimal zero-level demanded then an observer is unconfident. ‘Decisional confidence’ is understood as original unconscious, appeared in any decision making and based on an evidence obtained in favor of the chosen alternative, while ‘post decisional confidence’ – as subsequent conscious estimation of a response correctness, which is given if needed. So the both kind of confidence may appear successively in the same observation. [2]

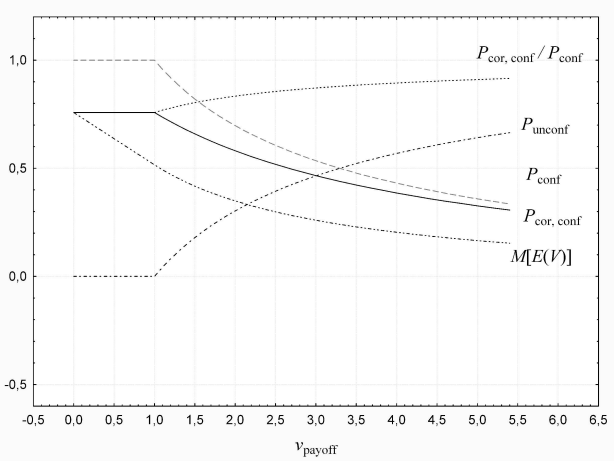

Figure 1. — Parameters for calculation: responses correctness probability $P_{cor} = 0.75$; constant correct responses costs $v_{cost} = 1$; erroneous responses payoffs v_{payoff} — variable. P_{conf}, P_{unconf} — confident and unconfident responses probabilities; $P_{cor,conf}$ — confident responses correctness probability; $P_{cor,conf}/P_{conf}$ — proportion of correct responses among confident ones; $M[E(V)]$ — mean expectable all-alternative utility.

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Storage: The standard features in memory

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The dynamics of storage the standard stimulus of different modalities was investigated by many authors. It was shown that observers can be stored a significant number of etalons in memory, and to compare with high accuracy the presented physical stimulus with one that is stored in memory. It was found noforgetting with time of storing the standard stimulus, but rather the accuracy of identification and discrimination increases. The purpose of the study is the experimental research of the dynamics of physical and semantic features of the standard stimulus during its storage in long-term memory.

We have selected as standard sound clip the birdsong in the forest (2449 ms) as the most pleasant, natural, well-known, strong stimulus opposed to other fragments: cat's meowing, dog-barking, call of the cuckoo, the sound of the falling drops, kick ax on a tree, scream walrus and chimes[1]. The survey was conducted individually and consisted of five series.In the first series the subject was presented the standard stimulus that he could hear a few times to memorize its duration. Then the subject measured the clip's features at the points of semantic differential.

The survey consisted of five series. In the first series the subject was presented the standard stimulus. After its memorization the subject measured the clip's features at the points of semantic differential (SD). After 20 minutes of storing the subjects reproduced the memorized duration of the standard stimulus pressing a key (20 times). The second series was carried out after 7 days. The task of the subject was to recall and reproduce the duration of the standard stimulus pressing the key, as well as fill out a form of semantic differential. The following series were similar to the second one and were carried out at 14, 21, 28 days after the first series.

The results of research identified the dynamic features of the subjective standard stimulus in the long-term memory storage. We found the shortening of the subjective duration of the standard from 1 to 4 series (from 20 min to 21 days of storage). During its storage the standard stimulus in memory increases the precision of its replaying. Analysis of SD results showed that after storage in long-term memory the standard stimulus was estimated as less natural, pleasant, familiar, ringing, and more tiresome, longer, final. Two groups of subjects were pointed out. We identified an underestimation of the duration of the standard stimulus in the first group and the overestimation in the second group in all five series. The analysis of variance demonstrated that the time of the storing of the standard stimulus in memory can explain less than 2 percent of variance.[2]

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Faces contextualized by faces: The similarity effect in face–context integration

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Facial expressions typically happen in contexts, making that information in a face is rarely the only one at play when observers judge expressions. This study investigates how contextual information provided by a set of adjacent faces is combined with the information conveyed by a focal face using the methodology of information integration theory[1]. Besides the general issue of the integration model, specific hypothesis were also considered: the claim by Susskind *et al.*[2] that context effects increase with physical similarity between contextual and focal information; the claim by Barrett and Kensinger[3] that context effects are larger for judgments of expressed emotion than of expressed action tendencies (e. g. approach–withdrawal).

Stimuli were 3-D synthetic realistic faces of three male and three female characters. Expressions arose from combinations of FACS-defined Action Units, in line with prototype definitions. Focal and contextual information were taken as factors, and varied along a bipolar continuum (sad–happy) with high intensity prototypical expressions at each end. This bipolar arrangement allowed for different degrees of similarity between focal and contextual faces. A general 5 (focal) $\times$ 5 (contextual) repeated measures design was used. Participants judged the focal expression as to conveyed 'dissatisfaction–satisfaction' in one experiment, and as to expressed 'approach–withdrawal tendency' in another experiment, using a continuous graphic rating scale.

Significant context effects were observed in both experiments. A close to additive model was found to govern the integration of contextual and focal information. However, slight but significant departures from additivity (convergence and divergences of lines) were also displayed in the plots, supporting the predictions from the similarity hypothesis. Two clusters of participants emerged, disclosing large context effects in one case (major cluster) and virtually no context effects in the other (minor cluster). While Masuda *et al.*[4] previously documented a modulation of contextual effects on the judgment of facial expressions by cultural differences (e. g. Japanese vs. North American participants), our findings highlight a key role of individual differences even within a same cultural background. At odds with Barrett and Kensinger[3], who used emotional words as contextual information, context effects were noticeably larger for judgments of action readiness (approach-withdrawal) than of expressed feeling. One likely interpretation for this result is that contexts defined by faces may entail direct implications as to the open courses of action within a seemingly interpersonal situation.

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Visual discrimination asymmetry: Decision making criterion, time order error

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Some authors have found 'Same' (*S*) responses were found to be given more often and in many cases more quickly than 'Different' (*D*) ones in spite of equiprobable presentation of same (*s*) and different (*d*) letters and dots patterns, circulars dimensions, human faces in *S*–*D* visual discrimination task. There is no conventional explanation of the phenomenon yet. In the present work discrimination in pairs of *s* (600 ms and 600 ms) and *d* (600 ms and $600-\Delta t$) light flashes durations was studied. Δt was chosen individually in order to obtain 70–80 % of correct responses. *s* and *d* pairs and a place of a longer duration in *d* ones were equiprobable and changed randomly. In each trial each of 71 observers gave 2 successive responses: 1) were *s* or *d* durations presented, 2) is he (she) confident or unconfident in his (her) 1st response correctness. After preliminary and training sessions a main session was conducted included 100 trials. *d*-trials were considered commonly to be signal ones and decision making criterion was estimated by Yes Rate-index. Statistical significance of discrepancy between probabilities of *s* and *d* trials (.5 and .5), and empirical frequencies of *S* and *D* responses, was estimated by Laplace theorem, and discrepancy between frequencies for different kinds of trials and responses by Wilcoxon Test.

It was found that 75 % of observers showed greater ($p < .003$) *S* responses frequencies (.56 in average) than *D* ones (.44 in average). These data are rather close to theoretical probabilities (.62 and .38 correspondingly) predicted by our model of confidence in sensory discrimination[1]. The model explains predominance of *S* judgments by responses distribution in *S*–*D* task. The empirical fact obtained did not depend on observers' cognitive styles: field (in)dependence, rigidity—flexibility, reflection—impulsivity (Spearman Correlation Test). In average frequency of confident *S* responses (.47) was 1.4 times as greater as confident *D* ones (.33, $p < .05$) and mean confidence of *S* responses was 2 times as nearer to the corresponding proportion correct as compared to *D* ones ($p < .01$). Time Order Error (TOE) was revealed: erroneous *S* responses frequencies were 1.7 times as lesser when the 1st stimulus was longer as when it was shorter than the 2nd one ($p < .001$). That is, durations were discriminated better when the 1st one was the longest. This corresponds to another authors' data for similar durations.

Predominance of *S* responses means observers' accepting of lax decision making criterion for these judgments while strict criterion for *D* ones. Lax criterion for equality was typical for 2 kinds of trials: where the 1st duration was shorter and in *s* trials. And a criterion was symmetrical only in the 3rd kind of trials: where the 1st duration was longer. It has to be discussed: 1) have we consider TOE and lax criterion for equality to be independent factors or is one of them caused by the other; 2) are *S* judgments more easier and therefore preferable and more confident than *D* ones?[2]

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Habituation vs. sensitization to pain in newborns

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Habituation to pain is an adaptation process which promotes a reduction in behavioral response to a given pain stimulus over time. This mechanism is not well described in the literature in neonates due to difficulties in characterizing pain in these individuals. The pain in newborns may be evaluated by behavioral and physiological parameters such as COMFORT Behavior Scale and skin conductance activity (SCA), respectively, analyzing the overall score scale and SCA through area under the curve (AUC) and number of peaks per second (NP).

The present study analyzed 14 newborns with a mean gestational age of 38 weeks ($\pm$2.18), 66 % males, birth weight of 3291 g ($\pm$922 g) and minute-5APGAR of 9 ($\pm$0.3). These subjects underwent five heel pricks for blood glucose curve during a period of 24 hours (0, 3, 6, 12 and 24 hours after birth). The last four events were videotaped and the SCA was measured by Skin Conductance Measure System (SCMS®) 15 and 30 seconds after pain events, investigating the effect of time elapsed after the nociceptive stimulus. Data was analyzed by repeated measure analysis over four repeated pain events and showed that there was pain habituation for SCA to the variable AUC at 15 s ($F_{(1,3)} = 36.99$, $p = .009$) and 30 s intervals ($F_{(1,3)} = 52.04$, $p = .005$). Also, with good correlation between AUC and COMFORT ($r = 0.98$, $p = .002$). However, there was no significant habituation effect observed to NP neither to scale response, although decrease in the mean values was observed specially to the 4th session, suggesting that there was a process of habituation to pain.

Overall, the classic gradual habituation process was not observed to the behavioral dimension, but a pattern of decrements and increments with a general tendency to decrease. The newborns scores at pain scale only attended the cut off score ($\geq$ 17) at 1st session, going down and up in the next events. The absence of continuous decrease in the scores for the 3rd session can be explained by the pattern of habituation model presented by Colombo *et al.*[1]. In their model, both functions of sensitization and habituation are considered to generate a third process called aggregated function. Hence, behavioral habituation to pain in neonates is better observed, therefore, by an aggregate function between sensitization and habituation while habituation was clear to the physiological parameter AUC. This observed phenomenon still needs more studies utilizing the psychophysical approach.

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Randomly interleaved staircases and 'acceptance thresholds' in computer graphics experiments

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Videogames and animated movies are populated by virtual human characters and inanimate objects which move and interact variously. A possible way for improving the realism of virtual animations is to mirror closely how humans and objects behave in the physical world. The drawback of this approach is that a huge number of variables should be taken into account, and this causes the growth of computational costs. A more effective approach is to exploit the limits of the visual system in order to create perceptually realistic animations while saving the computational costs of details that observers cannot perceive.

Psychophysical experiments can provide valuable quantitative guidelines for animators who wish to decrease the physical realism of virtual animations, and thus their computational costs, without compromising their perceptual realism. In these experiments, acceptance thresholds are measures quantifying how much a physical variable can depart from its ideal value while still being perceived as plausible with a reasonable probability. In experiments where the independent variable can be manipulated along a continuum, randomly interleaved staircases with fixed step sizes is a quick and simple psychophysical method for obtaining acceptance thresholds. With optimal setup, this method provides accurate and precise threshold measurements [1].

Typically, the observer is asked to judge whether the presented virtual animation is *natural/correct* or *unnatural/incorrect* with respect to his/her previous experience with the corresponding physical event. According to the staircase design, the *ascending staircase* starts with the most physically realistic animation (which is perceived as clearly natural/correct), while the *descending staircase* starts with the animation which differs most from physical reality (the animation is glaringly unnatural/incorrect). For each staircase, the value of the independent variable is increased by a predefined amount after a *natural/correct* response, and decreased by a fraction of that amount [1] after a *unnatural/incorrect* response. The two staircases are randomly interleaved in order to avoid anticipatory effects. Each staircase stops after a pre-specified number of response changes, and the acceptance threshold is then computed by averaging the physical values corresponding to response changes, or by fitting a psychometric function to the data. The poster we present shows that this method has proven being effective in graphics experiments on rigid bodies collisions [2] and virtual throwing animations [3].

Computer graphics is a promising field of multidisciplinary research. On the one hand, animators need effective psychophysical methods for measuring acceptance thresholds. On the other hand, psychologists may increase their understanding of the visual system through research in computer graphics, which is typically carried out with realistic ecological stimuli.

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Haptic sensation elicited by visual stimulation: The "feeling by seeing" procedure

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The effectiveness of minimally invasive surgery robots is limited by surgeon's lack of haptic sensation while remotely operating the robot. Thus, the reconstruction of haptic sensation has become an important research goal. Here we report an experimental procedure in which visual stimuli successfully evoked haptic sensation. Participants performed stylus-tracking of predefined paths on silicon surfaces, while required to maintain constant stylus pressure (measured by WACOM graphic tablet). Visual feedback on pressure was provided as a color signal (color performance track-lines displayed on the task screen) and as a visual dynamic cue: A pulsating ellipse displayed on the surrounding perimeter of the wide display task screen (at 75° binocular visual angle). Its pulsating frequency reflected stylus pressure.

The stylus tip constituted a randomly rotating "Landolt C", requiring a secondary gap-detection task. This attention demanding resolution task ensured the peripheral visual cue to be unattended.

Comparing acquisition phase performance with the 3 feedback-type trials (Peripheral-only, color-line-only, and no-feedback conditions), pressure was efficiently maintained in the color-line-only condition, as expected, and in the Peripheral-only condition. Performance significantly declined in the no-feedback condition. Results indicated the peripheral cue as a significant feedback, although unattended.

In a second test phase we utilized virtual surfaces (no contact between stylus and tracking surface). Here "Pressure" was computed based on calibration scale of stylus tip elevation from the WACOM graphic tablet. This study yielded similar results: The peripheral cue served as feedback. Moreover, participants reported subjective haptic sensation while "touching" the surface, and in congruence with required stylus pressure. Our results support the feasibility of a stimulus-substitution processing whereby haptic sensation is elicited by a non-attended peripheral-visual stimulus.

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Special symposium

“Ernst Mach’s legacy: Psychophysics and beyond”

Ernst Mach – examples of his scientific work in the area of applied physics and measurement techniques

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The achievements of Mach in the areas of optics, acoustic, gas dynamics and Ballistics are of essential importance in the physics of 19/20th century. His criticism of Newton and the purely mechanical interpretation of physics made him one of the scientists to prepare the scientific community for Einsteins relativity theory. In the heritage of our Ernst-Mach-Institute was a letter from Einstein to Mach, discussing this point. Although in German, this very personal letter from Einstein to Mach will be presented.

In detail, Mach was one of the first physicists to analyze and understand the physics of shock waves in air. Shock waves are inherently coupled effect of fast moving masses in air, as for example a projectile, fired by a gun. To quantitatively measure and visualize such shock waves, he developed new photographic techniques and thus created the first photografies of shock waves in air. The wealth of his experimental results is now stored and conserved at the Deutsche Museum in Munich.

The Fraunhofer Institut für Kurzzeitdynamik in Freiburg, carrying the name of Ernst Mach, continues at least partially some of the ground breaking work of Mach in the area of applied physics. Nowadays of course the laboratories and their equipment are much more advanced going far beyond Mach's experimental work. Nevertheless the links to Mach's leading work will become obvious by comparing results from the 19th century to actual data. Typical applications of the work are today in the areas of security research, aerodynamics and space research. A few typical examples of modern research work will be presented and discussed.

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Mach on Helmholtz on acoustics

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It is well-known that Mach's and Helmholtz's approaches to sensory physiology deeply differ from each other involving also a disparity in philosophical outlook. This is particularly apparent for space and color perception where Mach is greatly influenced by Gustav Theodor Fechner and Ewald Hering. To use the terminology Helmholtz introduced, Mach clearly sides with "nativism", whereas Helmholtz himself favors "empiricism". A "nativist" is someone who tries to identify a "neural correlate", as we would call it today, of a perceptual capacity, whereas an "empiricist" would postulate that such capacity is the result of a psychological learning process.

In the case of tone perception, however, the situation seems not as clear-cut, at least at first sight. Mach wrote an enthusiastic review of Helmholtz's *On the Sensations of Tone as a Physiological Basis for the Theory of Music* of 1863 (engl. transl. 1875) which three years later led to a short manual on the same work. The goal was to explain in a popular manner the basic features of Helmholtz's theory to musicians. In this pamphlet, Mach praised Helmholtz's musical theory for "grounding the laws of tonal art in simple physical and physiological laws and bringing acoustics, musical theory and esthetics in relation to each other." Mach was even convinced that Helmholtz, as he wrote, had "justified his theory to such a degree that the correctness of its essential features cannot be taken into doubt anymore." From this it seems indeed hard to imagine that the antagonism of nativism and empiricism could have played a role in the acoustics of the two sense physiologists. It seems as if Helmholtz and Mach had indeed met on the common ground of acoustics irrespective of their dispute mentioned.

However, from the beginning of his work on acoustics and his reception of Helmholtz, Mach characterized Helmholtz's approach as incomplete. He claimed that several relevant phenomena are not covered by Helmholtz's explanation. He maintained for example that Helmholtz is unable to explain the sense of pitch and of musical intervals. We can immediately identify the order of three different sounds and compare intervals between them with other intervals on different scale locations even if they do not have any partial tones in common. Generally, Mach looks for additional physiological mechanisms where Helmholtz is content with assuming one nerve fiber for each sensation of tone and with reducing other perceptual phenomena either to the coincidence of partial tones or to special psychological processes. Later, Mach tried to expand on Helmholtz' theory by assuming not one but two specific sense energies for each tone by drawing an analogy to Hering's nativist opponent theory of color.

In my talk, I shall present Mach's criticism of Helmholtz's acoustics in detail and will show how it unfolded over the years until it reached its culmination in Mach's *Beiträge zur Analyse der Empfindungen* (1886). In conclusion, I shall reflect on the nativism–empiricism-controversy and the different role psychological explanation plays in the two approaches.

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Mach on 'monocular stereoscopy'

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Mach's discovery of the Mach Bands and the lateral inhibition mechanisms hypothesized to cause them is well known, although the mechanisms remain deeply contested. Mach's attempt to extend these ideas into a theory of so-called "monocular stereoscopy"[1] is less well known. This episode has historical and philosophical interest because it is illustrative of Mach's method in psychophysics, in particular his theory of elements and functions.[2]

Mach hypothesized that the brightness of a sensed point in the visual field was proportional to departures from the mean of the brightness of neighboring points and set the deviations proportional to the second derivatives of the luminance distribution (the physical stimulus). The first derivatives were barely noticed but they played a different role for Mach, that of triggering monocular depth sensations. A steadily lightening or darkening distribution was barely sensed as a change in lighting at all but instead was sensed as a surface of uniform brightness in space, such as a cylinder or a tilted wall. Other sensations of direction, size, and orientation in space were reciprocally affected by light and depth sensations connected together like the parts of a machine, as illustrated by Mach's visiting card illusion.

Mach also advanced several other hypotheses in connection with monocular depth sensations. For example, he believed that there was one space sensation of depth, not separate sensations for monocular and binocular vision, although there might well be two sorts of triggering mechanisms. Mach's experiments with the pseudoscope seemed to confirm this, where monocular cues seemed to override binocular disparities. Mach seemed to think that the monocular depth sensation was more primitive in the visual system and earlier in the organism's evolutionary history and that binocular fusion somehow enhanced depth sensations already present in the single visual fields, as for example in Hering's contemporaneous theory. He also seems to have realized on his own that the two eyes could fuse the monocular depth sensations of two wavy light surfaces directly without identifying monocular contours.

Mach's ideas led me to consider a monocular stereogram[3], a single surface with overlapping double images, to see if the single eye is also capable of fusion. I did eventually find attempts to construct these images, in fine arts and studies of diplopia, but the effect is probably better explained by the relative blur of the doubled images. Today I can think of a better reconstruction of Mach's idea, namely that the binocular fusion of directional sensations occasions the sort of concomitant automatic changes in orientation and depth in the two monocular images that allows them to fuse, as if the monocular images behaved like coupled Mach cards. Mach's approach differs in an interesting way from contemporary approaches to the still unsolved problem of binocular fusion. Mach requires a direct "phenomenological" functional connection between the observed sensations on both monocular surfaces, where the connection can also be observed directly. This is illustrative of his general method in psychophysics.

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Mach's concept of phenomenological science, and its relevance for psychophysics

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Mach, being a physicist and not a professional philosopher, never expounded his 'philosophy of science' in a systematic manner. His thoughts and views on the subject are scattered through his major works (*Analysis of Sensations*, *Mechanics*, *Knowledge and Error*) and minor essays. However, the main ideas can be safely reconstructed: (1) replacement of causal explanations by functional relations, (2) conception of scientific knowledge as economical description of observed phenomena, and (3) critique of theoretical constructs as provisional aids of questionable ontological status. The ultimate aim of science, in his view, was mathematical representation of the total nexus of natural phenomena—a program Mach called 'phenomenological physics'.

Important are Mach's analyses of mediation between experience and its mathematical model, e.g. in his studies on the definition of mass [1], or of temperature scales [2]. What enters the functional relations are not the observer's sensations as such but their metric representations, their 'labels' or 'signs of signs' [2]. Studying a measurement problem, one is facing an interplay between the procedural definition of the measured property, and its theoretical context, and balancing arbitrary choices on both sides of the problem. This leads to a more general problem of specification of 'forms of forms'—i.e., classes of admissible functional representations—that can be traced from early phases (dimensional analysis) via studies of functional equations to modern theories of meaningful descriptions, or 'forms of possible laws'.[3] For Mach, the task of science is specification of functional schemes, not assertions about the (hypothetical) underlying mechanisms.

The opposition between the mechanistic and functional approach is well illustrated by relation between statistical mechanics (micro-level) and 'phenomenological' thermodynamics (macro-level). Similarly, the brain's action can be studied on the micro-level, in terms of neuronal states and interactions (statistical neurophysics), or in terms of meaningfully defined macroscopic states.[4] Psychophysics since Fechner's *Elements* aims at schematic functional descriptions: not as a surrogate for exact knowledge of neural mechanics, but as a research program with its own merits. Indeed, *schematic representation* on a macro-level is not a defect of the theory relative to the micro-level, not a lack or loss, but rather a discovery, i. e. *incremental knowledge*.[5]

This idea is continued in the program of 'integral psychophysics' [6] that does not want to be merely an ancillary discipline for psychology or neurophysiology, but shall be a rigorous mathematical study of relational structures of primary experience, out of which subdomains of physical, physiological, or mental phenomena (and their respective levels of descriptions) emerge.

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Mach and Schlick on simplicity in science

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After receiving his doctorate under Max Planck, who provoked the famous debate on the nature of scientific knowledge with Ernst Mach around 1910, young philosopher Moritz Schlick continued the argument with proponents that he and Planck designated as 'positivists'. Although Schlick was influenced by Mach, he repeatedly took sides with Planck criticizing concepts brought forward by the 'positivists'. Schlick's criticisms targeted a central idea of Mach's psychology of knowledge, the principle of economy of thought. Now, what do Mach and Schlick understand by 'economy' and 'simplicity', respectively? What is Schlick's objection to Mach?

According to Mach, science as a systematic presentation of facts is basically an economical endeavor, meaning that scientific theories are developed with the objective of saving the trouble of new experience, of mimetically reproducing facts, and, most importantly, for the purpose of a more sparing utilization of our mental powers[1]. E. g., Mach accepts the assumption of theoretical entities, but only for practical reasons. Nonetheless, he regards them as provisional auxiliary means that postulate abstract attributes we are not familiar with in our experience. These provisional means ought to be replaced by assumptions that originate naturally and possess continuity with familiar experiences[2]. Compared with the abstraction of theoretical entities, concepts and theories artlessly developed in the course of an extra- and interpolation from empirical facts are better at meeting the requirements of economy of thought.

Despite the fact that both agree with the claim that scientists seek to present facts in an economical form, Schlick is not convinced that Mach's psychological interpretation of the principle of simplicity in science is right. In Mach's view, we tend to achieve scientific aims with as little effort of mental labor as possible. What counts as 'knowledge', therefore, has to satisfy the demand of convenience of thought. Schlick calls Mach's principle a principle of 'laziness' and claims that Mach deals with it only as a psychological phenomenon relating it with aspects of habit, convenience, and familiarity.[3]

Schlick, however, understands 'simplicity' as a logical notion, apparently, later affirmed by Einstein and Laue. Schlick names it the 'principle of economy of concepts' that has nothing to do with an ease of thought processes. We should favor those theories that presuppose fewer basic premises from which a theory is derived. Schlick's principle also demands economy with regard to a theory's formal coherence.[4] But his principle is not only a methodological consideration regarding the elegance of a theory, interestingly enough, Schlick also thought of it as an indicator of the level of knowledge a theory contains[5].

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Mach at younger ages, his research on psychophysics, his subsequent world view and his contribution to education

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There are some papers of Mach on psychophysics as an area of expertise to demonstrate to young students of medicine the physical functioning of the human body. These papers including his "Compendium der Physik für Mediciner"[1] were well known in Europe as a basic course on that topic for long time. Mach changed his scope to a more general view of the functionality of the human body including the brain as his responsibility moved to students of physics. His view as a scientist with *Erkenntnis*theory started early. That's why he lifelong tried to avoid contradictions, to avoid as much as possible a priori assumptions (at least to call them by name) and to find and adjust a monistic view.[2] This led him, step by step, to corrections of some of his early assumptions. His view at the end of his life unfortunately was not condensed in a book by himself, so this has to be done piecewise from his writings[3].

Mach's sensualism, perception, *Erkenntnis*theory and his Gestalt idea had a huge impact on education, especially on A. Binet[4] and W. James[5]. Because of the World War 1 and the death of the three, Mach's view collapsed and 150 years later becomes visible by statistical means and the access to Mach's, Binet's and James' writings by internet. In the meantime until now it is cultivated by Gestalt psychologists (for example by Ch. Bühler, Eino Kaila, R. Hönigswald[6], Heinz Werner; with the exception of Kaila they had to leave Germany after 1933 and are unknown in Germany now) to theory and praxis of international science education[7–9].

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Psychophysics as world view: Ernst Mach's sensualism, gestalt and *erkenntnis*-theory

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150 years ago in 1863 (only four years after Darwin had published his "Origin of the Species" in 1859), Ernst Mach took the idea of psychophysics from Fechner and developed it into a consistent world view. For Mach, it is thought-economical to use one perspective as a "general currency" through which one can compare and even exchange and generalize concepts from different domains or disciplines. The idea of psychophysics, i.e. that certain phenomena are in-between the psychical, physiological and the physical perspectives, fits very well to this question of what is general in science. If one takes psychophysics as a relation between the psychical and the physical perspectives and one can make the psychological, physiological and physicalist theories used consistent to each other, there is no need anymore for arbitrary epistemological "cuts". Such cuts lead to many – often unconscious – inconsistencies. For Mach, it is like walking on two legs, the physical and the psychical and assuming that the world one's legs walk on is the same for both.

This view of psychophysics was not shared by Fechner. Interestingly, in their correspondence (see Thiele 1978), Mach relied on Herbart's psychology (seemingly against Fechner's more physicalistic and metaphysical view). But in his books, Mach rather applied ideas of Heraclios he found in Herbart's early Neokantian counterpart in psychology, Friedrich Eduard Beneke. Thus in criticism to Herbart, Mach transformed Beneke's psychology into his psychophysical sensualism. To this he further added the thought-economical concept of gestalt. Gestalt is understood by Mach as adaptation and transformation, like in a Darwinian species. This is the transformed post-Darwinian gestalt concept which von Ehrenfels and Wertheimer took as a specific concept from Mach. Machian gestalts are process and product at the same time, which is fundamentally different from an Aristotelian "holistic" gestalt concept still used by Goethe. The transformed gestalt concepts has since been used by gestalt theory. Finally, in order to stabilize the new psychophysical world view and to make it consistent, Mach (still consistent with Beneke) developed an *erkenntnis*-theory based explicitly on *erkenntnis*-psychology and not only on *erkenntnis*-logic.

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