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# Fechner Day 2014

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18 – 22 August.

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# International Society for Psychophysics

Founded in Cassis, France, 22 October 1985

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# Preface

*Välkommen* to the beautiful city of Lund in the province of Skåne, southern Sweden. It is an honor to host this year's 30th Annual Meeting of the International Society for Psychophysics (ISP) in Lund. Historically, Lund is one of the oldest cities in Sweden dating back to 990. Combining historic tradition with a young student population, Lund is a safe city with vibrant academic character, quaint cobble-stoned streets and, befitting of a young healthy population, bicycles.

When Fechner presented his new transdisciplinary idea of "Psychophysik", he detailed a scientific method for studying relations between the physical and mental world of sensation and perception. Theoretical and methodological advance are still in focus today. This year, we are pleased to hear Hannes Eisler's tips from 55 years' research experience. In addition, the ISP and program committee are pleased to invite three speakers: Louis Narens, Simon Grondin, and Michael D. Lee. They are set to give stimulating talks on the scientific foundations of Stevens' power law, Weber fractions for time perception, and Bayesian methods for analyses of psychological models and data. We thank the Swedish Research Council ("Vetenskapsrådet") for providing funds to invite speakers from outside Sweden to this year's conference.

Adding to the diversity of the meeting, three theme sessions are planned by Rosana Tristão, Leah Fostick, and Åke Hellström. These theme sessions focus on "what's new in pain perception", "individual differences in psychophysics", and "crossmodal and supramodal psychophysics". The welcome inclusion of these theme sessions promises to provide for lively discussion. Moreover, we have numerous fine free talks and posters related to the many aspects of psychophysical research. The presence of those directly concerned with the study of psychophysics, along with others who make use of psychophysical techniques, will ensure for a lively meeting of delegates at this year's Fechner Day conference.

We thank the local city council for sponsoring the welcome reception. We also thank Jiří Wackermann, last year's conference organizer, for his invaluable help to get started and counsel. Also supporting the conference is Lund University who we thank for administrative support and for access to the university buildings situated, in splendid grounds, in the heart of Lund.

We hope you enjoy the conference, stimulating intellectual discussions, and the relaxed ambience of Lund.

Welcome to Lund
Geoff Patching

# Fechner Day 2014
## Scientific Program and Meeting Schedule

Note: All conference sessions and the business meeting of the ISP will be held in Palaestra et Odeum, University Square. The Gala dinner will take place in the Main University Building.

| | **Monday, August 18** |
|---|---|
| 16.00 – 18.00 | Welcome reception: *Auditorium, Main University Building* |

| | **Tuesday Morning, August 19** |
|---|---|
| 8.45 – 09.15 | **Welcome and announcements**<br>Annika Annerby. *Mayor of Lund.* |
| 09.15-10.15 | **Free talks** |
| | Viktor Sarris<br>*Adaptation-level theory in retrospect: a modern evaluation.* |
| | Jana Birkenbusch and Wolfgang Ellermeier<br>*Axiomatic evaluation of k-multiplicativity.* |
| | Riccardo Luccio<br>*Gassendi, the sun, and the apparent size.* |
| 10.15-10.45 | **Coffee break** |
| 10.45-11.45 | **Keynote speaker** |
| | Hannes Eisler<br>*Some research tips from 55 years' psychophysics.* |
| 11.45-12.30 | **Free talks** |
| | Stephen Link<br>*Theory of ideals and its application.* |
| | Michele Vicovaro and Luigi Burigana<br>*A diagnostic of the size-weight illusion by lines of subjective equality.* |
| 12.30-13.30 | **Lunch** |

| | **Tuesday Afternoon, August 19** |
|---|---|
| 13.30-15.30 | **Theme session**: *What's new in pain perception*?<br>Convener: Rosana M. Tristão |
| | Gunnar Borg and Elisabet Borg<br>*To determine the magnitude of pain with Borg CR-Scales®.* |
| | Beatriz Ferreira Neves and José Aparecido Da Silva.<br>*The challenge of pain.* |
| | Diana Kornbrot<br>*Quantified selves: mobile monitoring of pain perception for life enhancement.* |
| | Armando Oliveira, Luís Batalha, Ricardo Viegas, Ananda Fernandes, and Joana Gonçalves<br>*Empirically driven improvement of the linearity of extant faces pain scales.* |
| | Claudia Charry<br>*Pain measurement in Latin America: Advances and challenges.* |
| | Rosana M. Tristão, Kelly Cristina Santos de Carvalho, and José Alfredo Lacerda de Jesus<br>*The impact of sleep disorders at perception of pain.* |
| 15.30-16.00 | **Coffee break** |
| 16.00-16.45 | **Free talks** |
| | Rasmus Bååth<br>*Characteristics and mechanisms of subjective rhythmization.* |
| | Emmanuel Ponsot, Patrick Susini, and Sabine Meunier<br>*The role of duration in global loudness evaluation of rising and falling-intensity sounds.* |
| 16-45-18.00 | **Poster session I** [List of individual presentations on page xii] |

# Scientific Program

| | **Wednesday Morning, August 20** |
|---|---|
| 09.00 - 10.45 | **Free talks** |
| | Boaz M. Ben-David, Meital Avivi-Reich, and Bruce A. Schneider<br>*Does listening in a second language mimic aging? Evidence from the timeline for segregating a speech target from a background masker.* |
| | Mark A. Elliott.<br>*Temporal aspects of subjective visual experience: Evidence from stimulus-evoked hallucination.* |
| | Hans-Georg Geissler<br>*Deciphering the brain's time code: From behavioral invariants to principles of neural organization.* |
| | Timothy L. Hubbard<br>*The varieties of momentum-like experience.* |
| | Érico Artioli Firmino and José Lino Oliveira Bueno<br>*Distances between modulating keys also shorten subjective time estimations in real music stimuli.* |
| 10.45-11.15 | **Coffee break** |
| 11.15-12.15 | **Invited speaker** |
| | Louis Narens<br>*Measurement-theoretic and philosophic foundations of Stevens' power law.* |
| 12.15-12.30 | **Group photo** |
| 12.30-13.30 | **Lunch** |

| | **Wednesday Afternoon, August 20** |
|---|---|
| 13.30-15.15 | **Theme session:** *Individual differences in psychophysics*<br>Convener: Leah Fostick |
| | Leah Fostick and Harvey Babkoff<br>*Perceptual strategies in spectral TOJ.* |
| | Jennifer Lentz, Nicholas Altieri, and James T. Townsend<br>*Differences in the integration of audiovisual speech versus non-speech signals.* |
| | Yaniv Mama and Michal Icht<br>*Individual differences in the production effect in memory.* |
| | Jiří Wackermann<br>*Universality versus individuality: Place for inter-individual differences?* |
| | Harvey Babkoff<br>*Conclusions and future directions.* |
| 15.15-15.45 | **Coffee break** |
| 15.45-16.30 | **Free talks** |
| | Kwee-Yum Lee, Chelsea Carratt, Jia Han, Roger Adams, Hae-Jung Lee, and Gordon Waddington<br>*Proprioceptive performance of the hands in Cartesian space.* |
| | Patricia Hannan and Eugene Galanter<br>*Psychophysical training effects on young children with autism.* |
| 16.30-18.00 | **Poster session II** [List of individual presentations on pages xiii - xiv] |

# Scientific Program

| | **Thursday Morning, August 21** |
|---|---|
| 09.00 - 10.15 | **Free talks** |
| | Harvey Babkoff and Leah Fostick<br>*Stimulus parameters determining the shape of spectral TOJ threshold distributions*. |
| | Miguel A. García-Pérez and Rocío Alcalá-Quintana<br>*Some remarks on the fitting of psychometric functions to psychophysical data on perception of duration*. |
| | Rocío Alcalá-Quintana and Miguel A. García-Pérez<br>*Parameter estimation for model-based psychometric functions of perceived duration.* |
| 10.15-10.45 | **Coffee break** |
| 10.45-11.45 | **Invited speaker** |
| | Michael D. Lee<br>*Applications of Bayesian graphical modeling to psychophysics.* |
| 11.45-12.30 | **Free talks** |
| | Thiago Leiros Costa<br>*Investigating sensory processes with transcranial direct current stimulation (tDCS).* |
| | José L. O. Bueno, Danielle M. Judice-Daher, and Henrique G. Deliberato<br>*The reinforcement magnitude of stimulus affects temporal discrimination and interferes with omission effects in rats.* |
| 12.30-13.30 | **Lunch** |

# Scientific Program

| | **Thursday Afternoon, August 21** |
|---|---|
| 13.30-15.15 | **Theme session**: *Crossmodal and supramodal psychophysics*<br>Convenor: Åke Hellström |
| | Helen E. Ross<br>*Cross-modal measures – the literary evidence.* |
| | David J. Murray and Marissa E. Barnes<br>*Putting feelings into psychophysics: Theodor Lipps (1905) on the perception of weight and other modalities.* |
| | Elisabet Borg and Gunnar Borg<br>*A range model and a schematized conception for intermodal comparisons.* |
| | Robert Teghtsoonian<br>*The Psychophysical Power Law: Dead or alive.* |
| | Åke Hellström<br>*Time-order effects and generalized subjective magnitude in crossmodal stimulus comparison.* |
| 15.15-15.45 | **Coffee break** |
| 15.45-16.30 | **Free talks** |
| | Tamar Gur and Daniel Algom<br>*Selective attention under Stress: Evidence from the Stroop effect.* |
| | Luiz G. Gawryszewski, Sarah C. deOliveira, Larissa V. Kamarowski, Marinna G. Repossi, Douglas M. Pereira, and Tacy G. deMartins<br>*Hemispheric specialization for responses to positive and negative facial emotional expressions.* |
| 16.30-17.30 | **ISP business meeting** |
| 18.00-22.00 | **Gala dinner**: *Pillar Hall, Main University Building* |

# Scientific Program

| | **Friday Morning, August 22** |
|---|---|
| 9.00 - 10.15 | **Free talks** |
| | John S. Monahan<br>*Learning mental rotation* |
| | Tzvi Ganel, Gal Namdar, and Daniel Algom<br>*Effects of magnitude on grasping.* |
| | Stanislava Antonijevic-Elliott and Susan Folan<br>*Does training in interpreting improve capacity of working memory and executive function?* |
| 10.15-10.45 | **Coffee break** |
| 10.45-11.45 | **Invited speaker** |
| | Simon Grondin<br>*It's about time to perceive, with or without Weber's glasses.* |
| 11.45-12.45 | **Free talks** |
| | José Alfredo Lacerda de Jesus and Rosana M. Tristão.<br>*Do NFCS subscores react similarly to physiological indicators under the psychophysical parameters' view point*? |
| | Nadine Kakarot and Friedrich Müller<br>*Perceived exertion and heart rate during long term ergometer work of young and older subjects.* |
| | Michelle Galanter<br>*The child's conception of space (revised).* |
| 12.45-13.00 | **Closing remarks** |

| | **Friday Afternoon, August 22** |
|---|---|
| 14.00 – 18.00 | After conference grill with Geoff and Maarit |

# Posters

| Poster number | **Poster session I (Tuesday, August 19, 16.30-18.00)** |
|---|---|
| 1 | Naomi du Bois, Aleksandar Aksentijevic, and Mark A. Elliot.<br>*Investigating the temporal and phase structure of oscillatory mechanisms in auditory binding.* |
| 2 | Elisabet Borg and Charlotte Carlberg.<br>*Scaling loudness with the Borg CR100 Scale®.* |
| 3 | Thiago L. Costa, Marcelo F. Costa, Adsson Magalhães, Gabriel G. Rêgo, Balázs V. Nagy, Paulo S. Boggio, and Dora F. Ventura.<br>*The role of V1 in size and depth judgment: a transcranial direct current stimulation study*. |
| 4 | Christian Graff.<br>*The "geometric difference", a meaningful measure of dissimilarities in psychophysics.* |
| 5 | Kristín Ósk Ingvarsdóttir and Geoffrey R. Patching.<br>*Context effects in perception and discrimination of paired bounce heights.* |
| 6 | Yaniv Mama, Vered Shakuf, and Daniel Algom.<br>*Distance is not objective: Distance differences between and within objects*. |
| 7 | Sergio C. Masin.<br>*Reappraisal of magnitude estimation as an adjunct method for functional measurement*. |
| 8 | Tetsu Miyaoka.<br>*A mathematical model to explain the quantity of Velvet Hand Illusion*. |
| 9 | Thomas H. Rammsayer.<br>*No evidence for an ISI-induced interference effect on temporal processing of empty intervals*. |

# Posters

| Poster number | **Poster session II (Wednesday, August 20, 16.30-18.00)** |
|---|---|
| 1 | Elisabet Borg and Chantella Love.<br>*Evaluating elite performance with the Borg CR100 Scale® in a Swedish championship in diving.* |
| 2 | Jee Ho Chang.<br>*Perceptual judgment of stimulus depth during fixation and saccadic eye movement.* |
| 3 | Timothy L. Hubbard and Susan E. Ruppel.<br>*The mind in the cave: perception of paleolithic paintings and petroglyphs*. |
| 4 | Francisco Carlos Nather, Arthur Shocken Gréggio, Carlos Ernesto Garrido Salmon, Antônio Carlos dos Santos, and José Lino Oliveira Bueno.<br>*Neural substrate analysis for visual motion perception and subjective timing*. |
| 5 | Andrée-Anne Ouellet and Claudette Fortin.<br>*Simultaneous timing: differential attentional processes and auditory dominance*. |
| 6 | Tina Plank, Katharina Rosengarth, Carolin Schmalhofer, Markus Goldhacker, Sabine Brandl-Rühle, and Mark W. Greenlee.<br>*Perceptual learning in patients with macular degeneration*. |
| 7 | Vered Shakuf and Boaz M. Ben-David.<br>*Beware of the bear: Cultural and linguistic differences in the perception of emotional speech.* |
| 8 | Taiga Tatsukawa.<br>*Effects of the distribution of durations of leading tones on the perceived duration of following tones* |

# Posters

| Poster number | **Poster session II (Wednesday, August 20, 16.30-18.00)** |
|---|---|
| 9 | Michael Thorpe and Aleksandar Aksentijevic.<br>*The priming effects of structural information on pitch interval judgements.* |
| 10 | Laura Ziebell, Heather Woods-Fry, Misha Sokolov, and Charles Collin.<br>*IAMFaRR: A tool to assess maximum range of face recognition.* |
| 11 | Lucia Zanuttini and Caterina Malisano.<br>*The lightness of "Ebbinghaus like" figures with illusory contours.* |

# Contents

# Parameter estimation for model-based psychometric functions of perceived duration

Rocío Alcalá-Quintana* and Miguel A. García-Pérez

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Subjective time duration is often represented as a random variable whose mean, $\mu$, is a non-identity function that maps objective time onto perceived time and whose standard deviation, $\sigma$, is proportional to duration. Models of performance on time-perception tasks typically incorporate a decision-response process that involves the parameters of $\mu$ and $\sigma$, and at least one decisional parameter. It has been shown that when these models are used with a paired-comparison ternary task, the resulting psychometric functions reflect sensory and decisional processes in an identifiable way, leading to experimentally testable predictions.[1] Yet, the utility of this framework ultimately depends on whether model parameters (i) can be estimated separately (i.e., they do not get inextricably blended in the model equations) and (ii) can be recovered from data with sufficient accuracy so as to discriminate among alternative scenarios. In this work we investigate both issues.

When the same stimulus serves both as standard and as test (i.e., standard and test only differ in physical duration) a single pair $\{\mu, \sigma\}$ governs observers' performance. Since perceived duration is expressed in subjective (arbitrary) units, model parameters can be estimated except for a location and a scale constant, but this does not represent a problem to fit model-based psychometric functions that adequately describe the data and help determine whether objective and subjective time run at a different pace.

When the standard and the test differ in some other aspect apart from physical duration (e.g. filled *versus* empty intervals), each type of stimulus entails its own $\mu$ and $\sigma$. In this case, sensory and decisional parameters can also be isolated and recovered from the data with sufficient accuracy. Parameter values for the test stimulus are expressed in relative units with respect to the corresponding parameters for the standard, which suffices again to determine whether subjective duration differs across the types of stimuli used as test and standard.

Examples of different scenarios are presented to illustrate these issues and to compare model-based psychometric functions with the alternative practice of fitting arbitrary psychometric functions to the data.

## Reference

1 M. A. García-Pérez, *Front. Hum. Neurosci.* **8**:415. doi: 10.3389/fnhum.2014.00415

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# Does training in interpreting improve capacity of working memory and executive function?

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Language interpretation is a process of converting a thought or expression from a source language into an expression with a comparable meaning in a target language. By definition, interpreters must be at least bilingual. A growing body of literature indicates that bilinguals have better executive function than monolinguals.[1] Additionally, simultaneous interpreting requires the interpreter to operate with relatively large chunks of language at the same time, which puts significant strain on their working memory, and also requires excellent executive control. In order to examine whether intensive one year long training in simultaneous interpreting improves capacity of working memory and executive function, we employed Forward and Backward Digit Span test and Stroop Number test.[2]

In both Digit Span test digits 1-9 were presented both visually and auditory in sequential order starting from 2 digits. The number of digits presented in each consecutive trial depended on the accuracy of the previous trials: Participants were required to correctly repeat all digits irrespective of their order in 3 separate trials in order for another digit to be introduced. The score was the total number of digits correctly recalled in the correct serial position. In the Forward Digit Span task participants were instructed to recall digits in the order they were presented while in the Backward Digit Span task they were instructed to recall digits in the reverse order.

The Stroop Number test was employed to test executive function in interpreters pre and post training. In each trial words ‘one’, ‘two’ or ‘three’ were simultaneously presented once, twice or three times. Participants were instructed to report either the number of words presented (count) or the numeric value of the words (digit). In the congruent condition, the numeric value and the number of words were the same (e.g. ‘two’ presented 2 times) while in the incongruent condition they differed (e.g. ‘two’ presented once). There were four conditions in the task: (i) congruent digit, (ii) congruent count, (iii) incongruent digit, and (iv) incongruent count. Each participant saw 6 blocks of 16 trials that were presented in random order.

Results indicated that there was no effect of training on the executive function measured by the Stroop Number test. However, significant effects of congruency and the type of report (count vs. digit) as well as their interaction was observed. While Forward Digit Span indicated significant improvement in working memory after the training, Backward Digit Span did not indicate any difference between pre and post training measurements.

To conclude, intensive one year long training in simultaneous interpreting improved a specific aspect of working memory measured by recalling digits in the same order as they were presented. The training significantly improved neither backward digit recall nor performance on the Stroop Number test.

## References

1 E. Bialystok, F. I. M. Craik, G. Luk, *Trends Cogn. Sci.* **16** 240–250 (2012).
2 J. H. Flowers, J. L. Warner, M. L. Polansky, *Mem. Cognition.* **7** 86–94 (1979).

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# Characteristics and mechanisms of subjective rhythmization

Rasmus Bååth*

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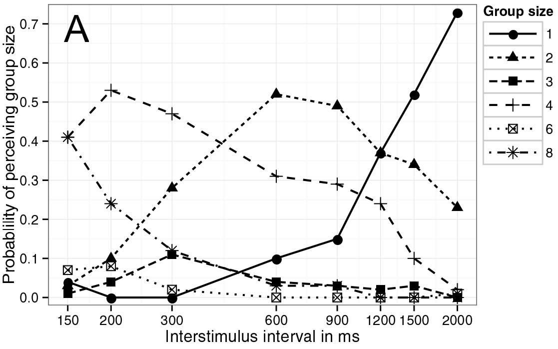
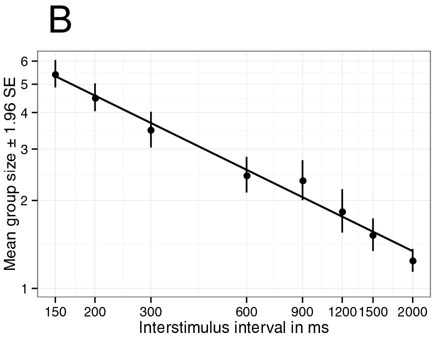
Subjective rhythmization is the perceptual illusion that the monotone sounds of metronome sequence have different intensity and that these differences follow a regular pattern. This pattern has a metrical structure and causes the impression that there are groups of sounds. Resonance theory, a dynamical systems theory of rhythm perception[1] has been used to explain why subjective rhythmization occurs. The present study aimed to replicate and extend the only two studies that have employed the original SR experimental paradigm[2,3] and to test a number of predictions developed using the resonance theory explanation. Nine female and 21 male participants were asked to attend to isochronous sequences of click sounds, presented at ISIs ranging from 150 ms to 2000 ms, and to report the first grouping they experienced. In addition, a synchronization task was administered in which participants tapped along to metronome sequences of different tempi.

The results of the current study are in accordance with earlier studies on subjective rhythmization. The most common groupings participants reported were two and four, the groupings of common meters of western music, and group size and tempo interacted as participants tended to perceive smaller groupings at slower tempi and larger groupings at faster tempi. Figure A shows the relative frequency of the reported groupings as a function of the interstimuli interval (ISI) of the monotone metronome sequence. A number of predictions developed from resonance theory were also confirmed by the experiment. The mean group period as function of ISI was found to be well described by a power function, as shown in Figure B. There was also a strong correlation between participant's responses in the subjective rhythmzation task and timing performance in the synchronization task.





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2 T. Bolton, *Am. J. Psychol.* **6**, 145–238 (1894).
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# Stimulus parameters determining the shape of spectral TOJ threshold distributions

Harvey Babkoff*[a] and Leah Fostick[b]

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Over many decades, spectral temporal order judgment (TOJ, monaural stimulation with two tones of different frequencies, separated in time, ISI) and spatial temporal order judgment (TOJ, stimulation of the two ears with two same frequency tones, separated in time, ISI) paradigms have been an integral part of the battery of temporally based perception tasks used to test and compare auditory temporal discrimination. The working hypothesis has been that, since the major independent variable manipulated is the ISI between the two stimuli, both paradigms measure "temporality", i.e., the ability of the auditory nervous system to differentiate order based on the identification of the individual elements in the pair of stimuli and the perception of the temporal order of the two stimuli along the time line. Consequently, a "threshold" for either paradigm was thought to represent the measured "limits" of the subject to perceive "temporality". The often reported very large differences in thresholds between the two paradigms (favoring spectral TOJ) were attributed to differences in either methodology or in the stimuli. However, we used the same stimuli (brief tones) in both paradigms and found significant differences between spectral and spatial TOJ thresholds.

In this study, we examined the impact of two stimulus parameters on spectral TOJ thresholds. Our focus is on the form and shape of the spectral TOJ threshold distribution, especially on the number of subjects whose spectral TOJ thresholds are in the 0-5 msec ISI range.

Spatial TOJ distributions plotted as percent of thresholds as a function of ISI in msec bins, appear almost classically Gaussian, with the mode at ISI = 6-59 msec or 60-119 msec. In contrast, spectral TOJ threshold distributions appear as Poisson distributions with one (left) mode or "inverted J" distribution with the main mode at ISI = 0-5 msec. The spectral location of the midpoint between the two tone frequencies significantly impacts the form and shape of the spectral threshold distribution. When the two tones are in the low frequency range (e.g., 300-600 Hz), the mode of the spectral TOJ threshold distribution may be elevated to around 80%. When the tones are in the higher frequency range (over 2kHz), the mode may decrease to $\sim$30% or less, along with an increase in the percent of thresholds at ISI between 6-119 msec.

Tone duration also has a significant effect on the shape and form of spectral TOJ thresholds. Tone durations of '10 msec or longer yield Poisson or "inverted J" distributions with a mode at ISI = 0-5 msec, but a tone duration of 5 msec yields a TOJ threshold distribution almost Gaussian in appearance with the mode at ISI = 6-59 msec. We are presently considering several possible explanations for these results.

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# Sources for age-related changes in the timeline for segregating a speech target from a background masker

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Listening to your native language spoken in a quiet environment is virtually effortless. However, the addition of competing sounds increases listening difficulty. The listener must perceptually segregate the target speech from the competing sound sources (stream segregation[1]). Our previous paper[2] showed that word recognition improved for young English-as-first-language participants (EFLs) as we increased the time-delay between masker onset and the target word onset. We argued that the prior onset of the masker by a few hundred ms allows representation of the masker as a distinct auditory object. In turn, this facilitated the listener's ability to perceive the target word as a second and distinct auditory object.

Notably, older EFLs were as good as younger EFLs when the masker was noise, but did not show any benefit of having a multi-talker babble masker precede the target word. We argued that both younger and older adults could rapidly build up the noise as an auditory object as the acoustic properties of the speech token and the noise masker differed substantially from each other. However, the acoustic and phonetic similarity between the babble and target word is likely to impede the formation of the babble as an auditory object. The poorer performance of older adults with a babble masker could be thus attributed to age-related auditory declines. An alternative hypothesis is that declines in older listener's linguistic and semantic processing abilities made it more difficult to perceive the word as distinct from the babble.

Here we investigate these two hypotheses. We compared our previous results with the ability of younger English-as-a-second-language (ESL) speakers to benefit from a delay between masker and word onset. Noting that hearing acuity and acoustic processing is the same for younger adults regardless of language experience. If the difficulty experienced by older adults with a babble masker reflected age-related declines in auditory processing, we would expect both young ESL and EFL groups to benefit similarly from word-onset delays. If younger ESLs perform like older EFLs with a babble masker, this would support the alternative hypothesis: Relating poor performance to age-related declines in phonemic or semantic processes.

Results: ESL and EFL younger listeners were comparable in the speed for segregating speech from both noise and babble maskers. These groups only differ in the asymptote of the functions. The data indicate that the unique difficulty seniors experience with a babble masker stems from age-related auditory degradation and not from semantic / linguistic differences. Taken together, the two studies are consistent with a sensory degradation account for age-related declines in cognitive tasks[3]. Apparent declines in performance in speech tasks may arise because the sensory information delivered becomes degraded with aging.

## References

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2 B. M. Ben-David, V. Y. Y. Tse, B. A. Schneider, *Hear. Res.* **290**, 55–63 (2012).
3 B. M. Ben-David, B. A. Schneider, *Aging Neurpsychol. C.* **16**, 505–534 (2009).

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# Axiomatic evaluation of *k*-multiplicativity

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Stevens' direct scaling methods[1] such as magnitude production or magnitude estimation typically use numbers to describe the size of one or the ratio of two different stimulus magnitudes. To check whether these numbers as used by participants and in the experimental instructions can be interpreted as mathematical numbers, i.e. whether a weighting function $W(\mathbf{p}) = p$ between perceived and mathematical numbers exists, the axiom of 1-multiplicativity[2] can be evaluated. 1-multiplicativity is satisfied, if the stimulus intensity resulting from a successive adjustment with ratio production factors $\times\mathbf{p}\times\mathbf{q}$ is equal to the stimulus intensity resulting from a single adjustment $\times\mathbf{r}$ with $r$ being the mathematical product of $p$ and $q$. Recent studies of duration perception[3] and other sensory continua showed 1-multiplicativity to be violated in the majority of tests.

Steingrimsson and Luce[4] investigated this "numerical distortion" and assumed a weighting function $W(\mathbf{p}) \neq p$ instead of veridical interpretation of numbers. Following their approach, this experiment examined whether the relationship between perceived and mathematical numbers can be described by an exponential function, i.e. whether the axiom of $k$-multiplicativity holds. To check the validity of $k$-multiplicativity, the stimulus intensity resulting from a successive adjustment $\times\mathbf{p}\times\mathbf{q}$ multiplied by a constant factor $k$ has to be equal to the stimulus intensity resulting from a single adjustment $\times\mathbf{r}$.

Therefore, the data of three different ratio production experiments with a total of $N = 35$ participants were analysed. The experiments basically differed in the size of the ratio production factors: In Experiment I, integers were used as ratio production factors $(p \geq 1)$, while in Experiment II, only fractions $(p < 1)$ were applied. In Experiment III, both $p \geq 1$ and $p < 1$ were intermixed.

In Experiment I, $k$-multiplicativity held for all $n = 10$ participants, whereas in Experiment II, it held for 9 of $n = 10$ participants. Experiment III revealed axiom violations for 13 of $n = 15$ participants. For the exponent of the exponential function describing the relationship between perceived and mathematical numbers, separate tests for fractions yielded $k > 1$ and thus a weighting function $W(\mathbf{p}) > p$, whereas integers yielded $k < 1$ and a weighing function $W(\mathbf{p}) < p$.

The results confirm the assumption that number representation in particpants is not veridical but follows an exponential relationship. However, fractions and integers are perceived differently. Furthermore, these results can explain a bias observed in the majority of ratio production experiments: When integers are used as ratio production factors, the adjusted magnitudes of successive trials often exceed the adjustments of single trials whereas when using fractions, in contrast, the outcomes of successive trials typically fall short of the outcomes of single trials.

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# Investigating the temporal and phase structure of oscillatory mechanisms in auditory binding

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Previous research examining the psychophysical mechanisms concerned with combining tonal signals into auditory Gestalten has revealed a rate (33 Hz) and time-specific reaction-time (RT) enhancement (i.e., latency shortening) for inharmonic tones[1]. The aim of the present study was twofold; firstly to investigate an enhancement effect that is dependent on a temporal relationship defined by the frequency of the oscillatory response, to see if it is confined to oscillations of 33 Hz, and secondly to investigate the presence of a protentive effect (i.e. seeking evidence for an advanced response) that may be revealed by an interaction of frequency and presentation time. Participants responded as rapidly and accurately as possible to the presence or absence of a target tone in the second of a sequence of two sounds ($N$ = 13). The parameters of these stimuli were designed to be proportionately equivalent to the 33 Hz stimuli in the paradigm which produced the previous RT enhancement.

The results revealed an inharmonic enhancement effect that was significant for all frequencies. However it was hypothesised that this advantage would be observed when the interval between the entrainer and target presented the target at precisely the same point in the oscillatory cycle as occurred during the 33 pps - 106 ms pop-out (enhancement of RTs to inharmonic targets). This was not supported by the analysis, perhaps because the ISI is more illustrative of persistence effects than essential to the oscillatory process. The replication of the 33 Hz - 106 ms temporal conditions for other frequencies has in fact yielded results that suggest the phase relationship is more general. By converting ISIs for each level of rate into fractions of the evoked oscillatory cycle and mapping the inharmonic target present (ITP) RT as a function of this cyclic phase, an anti-phase relationship was revealed. Thus the RT advantage for inharmonic tones cannot be explained simply by the phase relationship between the primed aGBR and the target. In fact the temporal relationship may be influenced by a slower internally generated frequency, as originally proposed in the General Phase Angle Hypothesis (GPAH)[2].

The suggestion is that when neurons in the oscillatory activity established by the prime are maximally deactivated (i.e. correspond to a phase angle of 180 °), sounds that elicit a slightly different neural response, such as inharmonics, become most salient. This supports the hypothesis that certain frequencies facilitate the feature binding process dependent on the temporal parameters of the oscillatory responses involved.

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# A range model and a schematized conception for intermodal comparisons

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The human brain is supposed to have a capacity for supramodal evaluation of information–interaction from several senses (often studied through fMRI). Gunnar Borg's Range Model is a theoretical framework for interindividual, intermodal and interdisciplinary comparisons. The model postulates that the total natural subjective dynamic range from zero (or the threshold) to maximum (or a terminal level very close to the maximal intensity) is approximately subjectively equal for all individuals[1]. Each individual experience is thus interpreted in relation to its position in the individual range, regardless of the size of the physical stimulus range. For interindividual and intermodal comparisons it is also important to have a good reference, a firmly schematized conception, with high interindividual agreement. A maximal perceived exertion has been found to work well for this purpose[2]. Perceived exertion is an emergent modality consisting of many symptoms and cues with several sensory systems involved in conveying information to the brain from the muscles, respiration, skin, joints etc.; and with several important physiological correlates (e.g., heart rate, blood lactate, ventilation, skin temperature).

In a questionnaire study the idea was investigated that, at least in some cases, what schematized conception is used will have importance. This should for example be true for modalities where individual experiences vary greatly, as, e.g., for pain. Modalities included were taste (sourness and sweetness), heaviness, loudness, brightness, fear, smell, and pain[3]. Two groups of 20 persons (10 men and 10 women) followed one of two instructions. Group A compared each item with their conception of a maximal heaviness (as "100") and Group B used item-specific (intramodal) references of "sourest", "sweetest", "loudest", etc., imaginable[3]. The cross-modal task of comparing different modalities to the conception of a maximal heaviness worked well. As expected there was a significant difference between the two kinds of instructions for pain (with a lower mean value for group B, $p < 0.001$), but, and more importantly, also a larger variance for group B. For most modalities, except for pain, the intramodal references ("sourest", "sweetest", "loudest", etc.) may thus be conceived of as similar across individuals as well as approximately equal to the reference of a maximal heaviness, or at least was used that way. For a modality, such as pain, where individual experiences may differ extensively, the cross-modal task of using the conception of a maximal heaviness should be preferred.

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# Scaling loudness with the Borg CR100 Scale®

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The Borg CR Scales® are general intensity scales suitable for most kinds of experiences and symptoms including loudness, but have predominantly been used for perceived exertion and pain assessment. Even if earlier versions have, the present Borg CR100 scale® has not, however, been tested on loudness.[1] The scales are constructed to give ratio data and exponents that mimic what is obtained with magnitude estimation (ME). To also give level determinations and for interindividual comparisons, verbal labels are placed on the scale in congruence with the 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] 36 university students (9 men and 27 women: mean age 22.4 years, s = 3.1 years) partook in a loudness experiment, scaling loudness with the Borg CR100 Scale®. All sounds, $S = \{40;\ 50; 60; 70; 80; 90; 100\}$ dB(A), were presented four times in the same randomized order to all subjects. Sounds were generated by NMATLAB script, presented through earphones (Sennheiser HD 580 Precision) in a sound proof listening room using a stationary computer (Windows 7 Professional with RME Fireface 400 external sound card, sampling frequency 48 kHz, 24 bit depth).

Geometric means of results obtained with the Borg CR100 scale® were $R = \{4.7;\ 7.3;\ 12.2;\ 19.2;\ 29.5;\ 51.0;\ 86.5\}$ thus ranging from approx. "Very week" to just below "Extremely strong". The power function, computed from individual geometric means, was $R = 61.7 \times S^{0.42} (r = 0.912)$ and thus similar to what has often been obtained with ME and also with previous versions of Borg CR scales[1,2]. Figure 1 presents the average power function. Coefficients of variation fell from 0.61 (40 dB) to 0.14 (100 dB), similar to what has been obtained for perceived exertion[3]. The latest Borg CR100 scale® thus works fine for scaling loudness of pure tones.

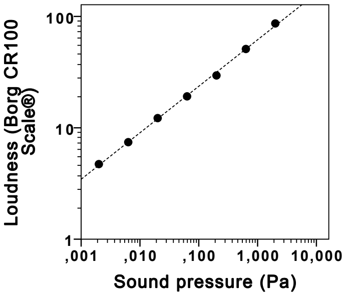

Figure 1: The psychophysical power function for loudness scaled with the Borg CR100 scale® ($n = 36$ subjects).

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# Evaluating elite performance with the Borg CR100 Scale® in a Swedish championship in diving

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In many sports, such as for example, in diving, figure skating and ski jumping, subjective assessment is essential in evaluating the performance. Judges usually score the performance according to a complicated setup of rules but uses quite simple rating scales. The Borg CR Scales®, commonly used for perceptual scaling of a variety of modalities and symptoms[1], may also be used for performance evaluation.

The Borg CR100 Scale®, is a general intensity scale from 0 to 100, "Maximal". For diving, "Maximal" was anchored in a "perfect dive". Five judges used the Borg CR100 scale together with the traditional scale for 4 men and 6 women who partook in the semi-finals in the Swedish Championships in diving, 2012. Judges were consistent in their way of using the scales, as can be seen from individual correlations with the contest results[2] (Fig. 1). Strong significant correlations were obtained between the traditional scale and the Borg CR100 scale® ($r = 0.80$) and for both scales with the contest results (0.63 and 0.62). With the Borg CR100 scale® several dives were assessed with a more precise differentiation between the dives. This is illustrated in Fig. 1 by the two individual dives no. 281 and 350. Since the CR100 is more finely graded, the scale gives a better flexibility in the judgments. Because the Borg CR scales can be used for self appraisal of for example perceived exertion, perceived difficulty, and motivation, the results in this study opens up an interesting field of possible comparisons in the study of performance enhancement and in the training of elite athletes.

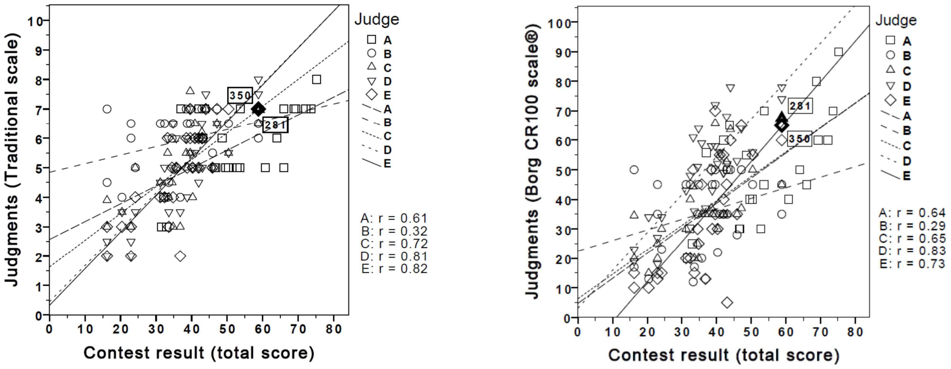

Figure 1: Judgments of dives in the semifinal with the traditional scale (left) and the Borg CR100® scale (right) from five judges.

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2 The judges that partook in the experiment were not the same as the ones judging the actual contest.

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# To determine the magnitude of pain with Borg CR-Scales®

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There are many demands on a good pain-scale. It should be possible to: use for all kinds of pain; determine direct levels of intensity over the total range; treat responses with statistical methods, preferably parametric statistics; study degrees of changes with stimulus intensity, medication and time; make interindividual, intermodal and psychophysiological comparisons; avoid ceiling and floor effects; make estimations and also productions; determine psychophysical S-R-functions, possible to describe with a general equations as, e.g., $R = a + c(S - b)n$, where $a$ is the basic "noise" at rest (or the absolute threshold), and $b$ is the starting point of the function; make two-way communication; handle round off tendencies; use internationally.

To meet these demands the scale must be constructed according to basic psychophysical and linguistic knowledge, and tested in relevant experiments. To cover the total subjective range there is a need of a number variation from 0 to 50 or a little more, about 26. Several anchors should be used that people understand very well, and that are placed correctly. Most existing scales do not fulfill these demands. A common drawback is that there is a too limited range, or a maximal endpoint defined as Highest (or Worst) Imaginable, which is not a schematized conception and problematic for interindividual comparisons. Examples are the Visual Analogue Scale (VAS), and the "Labeled Magnitude Scale" (LMS) for oral sensation[1]. On the LMS verbal anchors are placed to give ratio data, but "Strong" is 34.7, "Very strong" 52,5. For general usage, e.g., in two-way communication for prescription of exercise, this is not good, nor does the scales facilitate predictions of max-levels from sub-max estimations.

The best scales are the Borg CR Scales® (CR10 and CR100). In these scales quantitative semantics is used by applying ratio scaling to determine interpretation, meaning position in the range for congruence between anchors (labels) and numbers, and preciseness meaning interindividual agreement[2]. It is especially important that the anchors for Zero and Maximal refer to schematized conceptions. A maximal magnitude is defined as a maximal perceived exertion and effort, for example a maximal heaviness. These ideas have been presented during several ISP meetings by G. Borg, last time in Freiburg 2013. The CR10 has been used in many studies, e.g., during tests of functional capacity and chest pain, and muscular-skeletal pain[3]. The CR100 scale has, however, a greater potential as a general scale making possible determinations of most kinds of perceptual magnitudes. An advantage over the CR10 is that decimals need not be used and that the dynamic range is bigger and more in accordance with the psychophysical demands. The extra constants in the power function can then better reflect the true sensory processes.

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# The reinforcement magnitude of stimulus affects temporal discrimination and interferes with omission effects in rats

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Reinforcement omission effects (ROEs) have been interpreted as behavioral transient facilitation after nonreinforcement induced by frustration[1] or behavioral transient inhibition after reinforcement induced by temporal control[2]. According to frustration theory, the size of the ROEs depends directly on the reinforcement magnitude. However, studies involving operant paradigms have presented difficulty to demonstrate this relationship[3].

The present study aimed to clarify the relationship between reinforcement magnitude and ROEs manipulating the magnitude linked to discriminative stimuli in a partial reinforcement fixed- interval schedule. Rats were trained on a fixed-interval 12 s with limited hold 6 s signaled schedule in which correct responses were always followed by one of two reinforcement magnitudes (0.5 and 0.05 ml of a 0.15% saccharin solution). After acquisition of stable performance, the training was changed from 100% to 50% reinforcement schedules.

Data showed that there was a discriminative temporal control during the signal, producing different response distributions depending on the reinforcement magnitude anticipated. The performance during the fixed-interval signaled by the larger magnitude stimulus was higher than during fixed-interval signaled by the smaller magnitude stimulus when recorded in the last seconds of fixed-interval, but smaller in the first seconds. These data indicated the effect of the reinforcement magnitude and the enhancement of timing during larger signaled magnitude.

In the trials after nonreinforcement, data showed that the responding was higher after the larger reinforcement omission than the smaller one, pointing to the magnitude effect on ROEs. Thus, the manipulation of reinforcement quality using the flavor of saccharin corroborates with the hypothesis that the reinforcement magnitude operates in temporal discrimination and omission effect. But, no increase in responding was obtained during periods after nonreinforcement compared with that immediately preceding ones, which did not support the behavioral facilitation approach of ROEs. More vigorous responding during the last seconds of fixed-interval signaled by the larger than smaller magnitude stimuli showed higher response rate after nonreinforcement of larger than smaller reinforcement magnitude. These findings are similar to results from other studies obtained with water reinforcement[3, 4]. The reinforcement magnitude linked to the schedule remain operating in the omission and the ROEs can be attributed to tracking of discriminative control, or in another terms, greater the reinforcement anticipated, greater the omission effect.

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# Pain measurement in Latin America: Advances and challenges

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Many efforts have been made in several countries in Latin America to improve pain relief[1,2]. Developments in other regions around the world have motivated and supported the work of many health professionals in Latin America. Several initiatives have been proposed to address issues related to palliative care, pain in infants and children, training for health professionals and guidelines for pain treatment (Asociación Lationamericana de Cuidados Paliativos, Federación Latinoamericana de Asociaciones para el Estudio del Dolor, Change Pain Latin America, eToolkits, childkind, clínicas de dolor, hospitales sin dolor, parámetros de práctica)[1]. All these efforts for improved pain management and treatment are closely related to appropriate measurement and assessment of pain. This, in turn, can be achieved by training the patients, family members, and health professionals.

Two of the most popular scales used in Latin American Studies for measurement of pain intensity are visual analogue scale and numerical rating scale. Many other scales have been suggested in different Latin American countries but most of them have no evidence about their psychometric properties. Likewise, few countries have evidence related to attitudes and practices among health professionals regarding pain assessment and management.

Some countries like Mexico, Brazil, Argentina, Peru, Venezuela, Colombia, and Chile have invested a large amount of work and resources for pain research. These efforts have generated specific policies and guidelines to improve patient quality of life through appropriate pain management[2]. Nevertheless, even in these countries, appropriate practices are not widespread, rather they are priority in some medical centers. There are still many patients who do not receive appropriate pain treatment.

The main challenges have to do with implementation of guidelines and policies in professional practice and identifying barriers to effective pain management. Many health professionals do not know how to evaluate and manage pain in an efficient way, for this reason specific training is necessary. On the other hand, it is still important to continuously work for improved availability of pain medications, specially opioids[2]. Finally, it is necessary to either increase the evidence about validity and reliability of many instruments that remain without any evidence about their psychometric properties, or include in Latin American guidelines only pain instruments that have been widely tested and are strongly recommended by international organizations.

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# Investigating sensory processes with transcranial direct current stimulation

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tDCS is a non-invasive brain stimulation technique that induces polarity dependent modulation of brain activity and has increasing popularity in basic neuroscience and neurorehabilitation research. It may be applied before or during behavioral tasks without discomfort or interruption of the underlying brain activity. In a number of cases it may help unveiling brain / behavior relationships, complementing imaging and electrophysiological methods. Stimulation in the anodal direction tends to increase brain excitability and stimulation in the cathodal direction tends to decrease it[1]. These effects may be relatively durable depending on stimulation parameters and are thought to be driven by "LTP-like" and "LTD-like" mechanisms[2].

The present talk will discuss the current status of sensory processing research using tDCS, with an emphasis on its coupling with behavioral and psychophysical methods. We will argue that coupling tDCS and psychophysical methods represents a precious strategy in current sensory processing research (although it is still underused). There are successful examples of tDCS use in investigations of underlying mechanisms of most senses and also multisensory integration.

tDCS may aid perception research in a number of ways. First, it can help to understand how a brain area is related to behavioral performance in one specific task. For example, tDCS could inhibit the activity of one brain area and lead to a performance improvement in a task. This may suggest that this area has an inhibitory role in that task. Also, increasing the excitability in one area may improve performance in a task, suggesting this area is involved in the processing of that task. The absence of tDCS effects in one task may also help establishing that one area is not significantly involved in processing one task.

Coupling tDCS and psychophysical methods may also help clarify how tDCS works on different kinds of tasks. Does it affect threshold level and suprathreshold level responses in the same way? Does it affect different cells groups in the stimulated area in the same ways? Psychophysical methods allow a precise evaluation of tDCS outcomes and are helping to clarify these issues. Recent results from our group (published[3] or under review) and others[4] suggest that different cell groups and different aspects of the behavioral performance may be affected differently by the stimulation. These findings suggest that although tDCS may not be very focal on the spatial domain, its effects may be very focal in the functional domain (at least in some circumstances). The above mentioned findings and arguments further support the use of tDCS in the study of the underlying mechanisms of perception.

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# The role of V1 in size and depth judgment: A transcranial direct current stimulation study.

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Recent research suggests that V1 plays an active role in judgment of size and depth[1]. One approach to investigate this issue is to directly stimulate V1 with Transcranial Direct Current Stimulation (tDCS) while testing size and depth perception with a psychophysical task. Anodal tDCS is known to increase brain excitability while cathodal stimulation is known to decrease it. Therefore, this will allow for a better understanding of how increased or decreased V1 activity affects size and depth judgment.

Fourteen subjects received separate sessions of anodal, cathodal and sham tDCS (Oz-Cz, 0.06mA/cm$^2$) in a randomized repeated measures design. The participants received 5 minutes of tDCS before starting the tasks in each session. Two tasks were performed in randomized order in each session: one for size and one for depth judgment. In the size task, the participant had to judge the size of a circle using another circle with a fixed size (50 pixels) as reference. The same was true for the depth judgment task (but the participant was instructed to judge depth). Power functions were fit to the results of the size task. The shapes of the results for the depth task were best fit by a logarithmic function.

Slopes and $R^2$ were compared with separate repeated measures ANOVAs with two factors: Task (size vs. depth) and tDCS (Anodal vs. Cathodal vs. Sham). There was a significant interaction between Task and tDCS, $F_{(2,26)} = 4.097, p = 0.02, \eta_p^2 = 0.23$, for the slope analysis. Post-hoc LSD test showed that the slopes were only significantly different from placebo during anodal stimulation for the size task ($p < 0.01$ while all other $p > 0.25$). There was no significant interaction between Task and tDCS for the $R^2$ analyses, $F_{(2,26)} = 2.32, p = 0.18, \eta_p^2 = 0.11$.

Anodal tDCS significantly decreased slopes, apparently disrupting size perception. Also, tDCS of V1 affected size but not depth perception. These findings suggest two hypotheses: that increased V1 activity disrupts size judgment and that size and depth judgment involve different mechanisms. Subject's results on the size task seemed to reflect a prothetic continuum while the results in the depth task seem to reflect a metathetic continuum. The differential tDCS effects on size and depth judgment may be interpreted as supporting the hypothesis of different physiological mechanisms underlying judgment in these two continua[2]. Also, the results further suggest a complex V1 involvement in the judgment of size tasks that go beyond simple feature detection[1], and supports predictive coding models and experimental findings that suggest higher order visual areas may inhibit incoming information from V1 through feedback connections when complex tasks are performed[3].

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# Some research tips from 55 years' psychophysics

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I shall mention some general research problems, my way of tackling them and experimental and theoretical studies to illustrate them. Basic or applied problems? Both! Examples of applied investigations are subjective experience of loudspeaker quality and of surfaces of building materials. In the following problem examples of basic research will be given. Views on validating results: statistics, repetition, *converging operations* (experiment demonstrating same percept for same stimulus independent of judgmental instructions). Context effects: Psychophysical or *perceptual invariance*. *Data equivalence*: the same data can be interpreted differently (Thurstone Case V and VI). Comments on our observers: they know better than the theorist. *Kill your darlings*: be aware that your theory might be wrong. *Functionalism vs. pointillism*: work with functions rather than capitalizing on statistical differences in single points. *Creative* research vs. *gap filling* research. Time perception in humans and rats. Here I shall give just one reference[1]. There I describe the course of a research project with all drawbacks from the failed attempt to use cheap but stupid mice rather than expensive intelligent rats to the change of journal editor who questioned my conclusions in an already accepted paper so that I had to add an appendix in which I proved him wrong. It shows also the impact of serendipity and the advantage of discussions with colleagues. Finally, the lesson on how to boast elegantly I will not give in this summary.

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# Temporal aspects of subjective visual experience: Evidence from stimulus-evoked hallucination

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Our understanding of human visual perception generally rests on the assumption that conscious visual states represent, in some qualitative fashion, the complex interaction between spatially structured variations in the ambient optic array and our visual nervous systems. The existence of visual hallucinations (or purely subjective visual experience) in a number of pathologies as well as in experimental contexts questions the assumption that what we see in the environment is necessarily determined by spatial structure in the distal stimulus. The experimental data go further by showing that conscious states of apparent vision (i.e. apperception) are triggered by temporal stimulation that does not ultimately relate to what is seen in the apperceptive field. We have shown that the subjective experience of complex colour and forms is evoked by flickering light and, critically that the incidence and type of subjective experience varies with flicker frequency and phase[1, 2, 3]. In this contribution I shall outline evidence that subjective experiences, perhaps also hallucinations, arise from dynamic systems states with very well defined temporal structure. This structure is both measurable and refers to well-known perceptual timing quanta leading in turn to novel and perhaps radical conclusions about the relationship between dynamic systems and perceptual (and perhaps more generally psychological) experience.

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# Distances between modulating keys also shorten subjective time estimations in real music stimuli

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Real and long music stimuli are not common in music cognition and subjective timing literatures. Previously, we found time overestimations for the first 90 s of the third movement of Berio's "Symphony for Eight Voices and Orchestra" and time underestimations for the first 90 s of the third movement of Mahler's Symphony No. 2.[1] Berio recomposed Mahler's symphony inserting large complexity in all its musical structures (e.g., pitch, rhythm, timbre, etc.). Participants were required to listen to stimuli and silently reproduce the duration just after each target stimulus prospectively. Models of subjective timing generally based upon cognitive storing such as storage-size[2], contextual-change[3], or even internal-clock model[4] can explain these data whilst predicting longer time estimation for greater amount of information or complexity.

Afterwards, we found synthetic 20–s long modulating chord sequences eliciting time estimations in inverse function of interkey distance with major impact for sudden key-change[5]. In Western traditional music, a key is a cognitive sense of hierarchy of tones and chords, and key-change is the passage from one key to another. Participants listened to just one music stimulus and then retrospectively (unexpectedly) reproduced its duration. The cognitive-storing time-models cannot explain such data. Considering interkey-distance increase as equivalent to information/complexity increase, one might expect time lengthening.

Alternatively, we proposed the Expected Development Fraction (EDF) Model stating that if an interkey distance is traversed during a time interval, an expectation of temporal development is evoked, one which is intuitively needed to traverse such distance in a "cognitively smooth" manner. This development seems to be longer than the perceived duration. The disproportion is applied to perceived duration leading to shortening of time. In simple words, for the listener, the time which might have been is longer than the time of the listened music, and if he/she is required to reproduce the music duration in this state, he/she reproduces a short time because the music seemed small.

In this study, we employed another real music piece called "Inspiração" by Brazilian composer Garoto which was handled regarding interkey distances unfolded by key-changes, properly played by a highly trained guitarist, filling the duration of 90 s. Participants listened to and then retrospectively reproduced the music duration in one trial. Once more, results confirmed EDF Model and did not confirm cognitive-storing time-models.

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# Perceptual strategies in spectral TOJ

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A number of studies have reported that the perceptual process of order judgment of two tones of different frequency (spectral temporal order judgments, TOJ) may involve two types of perception: (1) direct perception of the two tones and their temporal separation, dependent on the inter-stimulus interval, i.e., the perception of the order of their occurrence; and (2) a holistic perception of the tonal patterns created by the order of the elements without separate perception of the elements and the judgment of difference based on the perceived differences between these patterns[1–4]. Warren[3,4] suggested that the same participants may use different strategies for discriminating sequences in different temporal interval ranges (ISI). In the current study we identified different strategies used by different participants for discriminating the same tonal sequences.

Participants performed spectral TOJ in which they reported the order of two 15 msec pure tones. The tones were 1 and 1.8 kHz and were presented at 40 dB SL. The order of the tones was randomly determined and they were presented with adaptively changing ISI in a two-down-one-up adaptive procedure.

The overall mean threshold = 65.594 msec (± 96.229). However, a close examination of the individual data showed that the distribution of thresholds is not Gaussian and may be separated into three patterns of response: 50% of the participants performed at 100% accuracy even with ISI $<$ 5msec, therefore their TOJ thresholds are defined as $<$ 5 msec; 23% responded with high accuracy for the longer ISIs and low levels of accuracy for short ISIs. Their thresholds ranged between 6-120 msec; and 27% were consistently incorrect at all ISIs used in the study. Their TOJ thresholds were identified as $>$ 120 msec (longer than the longest ISI duration used in the study). These results are consistent with previous studies on spectral temporal order judgments TOJ[5] that found similar threshold distributions for spectral TOJ.

We posit that these response patterns reflect different perceptual strategies. Borrowing from Warren's hypothesis[3,4], we suggest that the subjects whose accuracy increases as a function of increasing ISI, use the direct identification of the elements in the sequence and the order of their occurrence as their detection strategy, while the subjects who perform the task (correctly or incorrectly) regardless of ISI duration, are either using global perception successfully or in the latter case, unsuccessfully.

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# The child's conception of space (revised)

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"*Both space and time are not found in the human infant; but intrinsically evolve by his cognitive energy.*" (Lotze, H., 1890)[1]

Developmental psychophysics emerges from Piagetian principals of children's spatial learning. These principals emphasize infants' experiences in the real world. However, the real 'world' has now expanded to include the computer world as well. Videogames and digital technology expose children to a quasi three-dimensional reality that can be manipulated by the child. Currently, Minecraft is one of the highest grossing and beloved videogames for younger children. It presents children with a rich virtual environment within which they can build and explore.

The symbolic understanding and representational systems that develop into adult cognition are being cultivated in a vastly different manner than in the past, now that children's experiences no longer involve only natural objects or three-dimensional toys[2,3]. Thus children have been exposed to a unique and novel way of perceiving the world. This has led to a measurable impact on the development of spatial skills: map making and map reading, understanding perspective, distance and scale comprehension, and even semantic interpretation[4].

Video games offer advantages and drawbacks to learning about space. Some types of perspective taking are only possible in a video game. For instance, the 'third person' perspective of the popular game, Lego Star Wars, allows the player to control an avatar whose line of sight is that of a first person, except that there is a much greater range of vision than in reality. Also notable, computer games often provide several perspectives at one time. A multi-perspective layout can be achieved through a split screen interface, or simplified maps of the terrain that remain in the corner of the screen.

Despite all of these enhancements of perspective, video games are constrained by the parameters of the programmer and by the confines of actual two-dimensional space. It is tempting to compare the experience of a video game player to that of a passive movie viewer, or to suggest that it is equivalent to play time with toys. However, video games make entirely different sensory demands, influencing the spatial understanding of today's children in unique and novel ways. Many studies have looked at different spatial skills as children interact with new technology[3,5]. So it is now time to reconstruct Piaget's original trajectories and organize a new psychophysical development framework. As Ash put it, "Videogames re-organize the very cardinality of the body itself."[3] We re-organize the study of the child's understanding of space.

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# Some remarks on the fitting of psychometric functions to psychophysical data on perception of duration

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Time perception is governed by two established principles: (a) Subjective duration often differs from objective duration, so that time seems to fly or slow down under certain conditions, and (b) the standard deviation of subjective duration increases with duration, something known as the scalar property. Thus, the subjective duration of a stimulus of objective duration $t$ is a (normally distributed) random variable with mean $\mu(t)$ and standard deviation $\sigma(t)$, where $\mu$ is not the identity function and $\sigma$ is not a constant function. Perception of duration is often investigated using methods such as the two-alternative forced-choice task in which each trial displays a standard duration $t_s$ and a test duration $t$ that varies across trials, and observers are asked to report which duration was, e.g., longer. A psychometric function is subsequently fitted to the data, and the mathematical form of this function is usually

$$\Psi(t) = \Phi\left(\frac{\alpha - t}{\beta}\right) \tag{1}$$

where $\Phi$ is the unit-normal cumulative distribution function and $\alpha$ and $\beta$ are free parameters. However, the two principles mentioned above imply that the mathematical form of the fitted function should instead be

$$\Psi(t) = \Phi\left(\frac{\mu(t_s) - \mu(t)}{\sqrt{\sigma^2(t_s) + \sigma^2(t)]}}\right) \tag{2}$$

Fitting this alternative function allows recovering the parameters of the non-identity function $\mu$ and the non-constant function $\sigma$. By replacing the entire denominator of the argument of $\Phi$ in equation (2) (which is a function of $t$) with the constant $\beta$ in equation (1), the scalar property is removed from the account of the data given by the fitted function; by replacing $\mu(t)$ with $t$ in the numerator, the identity function is implicitly assumed to govern the relation between objective and subjective time; finally, by replacing also $\mu(t_s)$ with the free parameter $\alpha$ in the numerator (instead of simply using $t_s$ according to the assumption of an identity $\mu$), the reference point given by the subjective duration of the standard is replaced with an arbitrary criterion. As a result of such replacements, equation (1) accounts for the data under the assumptions that (a) subjective time does not differ from objective time, (b) the variance of subjective duration is constant and independent of objective duration, and (c) observed shifts of the psychometric function are caused by decisional criteria and not by differences in subjective duration across stimulus types.

This paper illustrates the consequences of the conventional practice of fitting data on perception of duration via equation (1). For this purpose, an affine form is used for $\mu$ (in place of the usual power form) and a linear form is used for $\sigma$. An experimental design is also presented that allows fitting equation (2) to the resultant data and recovering the parameters of $\mu$ and $\sigma$.

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# Hemispheric specialization for responses to positive and negative facial emotional expressions

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There are two main models of brain asymmetry in emotional processing: the right hemisphere and the valence hypotheses. The first states a dominant role for the right hemisphere in emotional processing, whereas the second assumes that the left hemisphere is dominant for positive emotions and the right hemisphere for negative ones[1].

Here, hemispheric specialization for responding to centrally presented Happy and Sad faces was investigated in forty volunteers. Choice Manual Reaction Time (MRT) when the right hand responded to a Happy face and left hand to a Sad face was compared to the reverse arrangement. The MRT were ordered and divided in quintiles. The means of MRT in each quintile were submitted to an ANOVA with Emotion, Response hand and Quintiles as within-subjects factors. All main factors were significant. MRT to a Happy face (415 ms) was shorter than MRT to a Sad face (426 ms) $F_{(1,39)} = 13.26, p < .001$, Left hand response (417 ms) was faster than Right hand response (424 ms) $F_{(1,39)} = 7.19, p < .012$ and, as expected, MRT increased with Quintiles $F_{(3,177)} = 368.32, p < .0001$. Moreover, there were two significant interactions: Emotion vs. Response hand $F_{(1,39)} = 4.29, p < .05$ and Emotion vs. Quintiles $F_{(3,177)} = 33.65, p < .0001$. The three-way interaction was not significant $F_{(3,177)} = 1.27, p > .28$. Post-hoc analyses showed that: a) Right hand response to a Sad face (434 ms) was slower $(p < .05)$ than all the other conditions, which did not differ among them (Right Hand response to a Happy face and Left hand responses to a Sad and to a Happy faces were 414, 418, and 417 ms, respectively); b) the faster response to a Happy face as compared to the response to a Sad face was significant just for the two first Quintiles in which the MRT differences were 23 and 12 ms, respectively.

Summarizing, it was observed that the response to a Happy face was faster than to a Sad face, but the shorter MRT to a Happy face varied according to the Response hand and to the latency of the response. The absence of a significant three-way interaction indicates that the longer Right hand (left hemisphere) response to a Sad face as compared to a Left hand (right hemisphere) response does not vary with the latency of the response. These results are in agreement with the hypothesis that the Left hemisphere is dominant for positive emotions because the Right hand response is faster to a Happy face than to a Sad face and that the Right hemisphere is specialized for negative emotion processing since that, for a Sad face, the Left hand response is faster than to a Right hand response[2].

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# Deciphering the brains time code: From behavioral invariants to principles of neural organization

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An unresolved problem of functionally oriented EEG research is the lack of a reliable independent definition of frequency bands. Recent attempts to solve the problem theoretically[1] capitalize upon the Golden Section as criterion ensuring maximally irregular phase relations between oscillations marking adjacent boundaries. These attempts suffer from their exclusive focus on limit frequencies delineated by negative constraining while failing to positively specify the manifold of potentially engaged options. Logically, alternatives meeting the requirement of positive specification rely upon global invariants of brain functioning. At variance with widespread belief, in their capacity as products of evolution, such invariants are readily detectable in behavioral rather than physiological data, where they may amount to only a minute fraction of precisely timed "winner" activity. Indications that global invariants exist were first put forward by Teghtsoonian[2] who showed that, in subjective coordinates Y, maximum range extension M = $Y_{\max}/Y_{\min}$ and the Weber Fraction C = $\Delta$Y/Y are approximate constants. Research initiated within the time-quantum framework TQM[3] that support this claim for temporal dimensions suggests M and C to be universal descriptors of relaxation of fuzzy synchrony of underlying oscillations of slightly differing cycle durations thus giving rise to a – so far ignored – reciprocal relation M $\cong$ 1/C.

An additional contribution of TQM consists of an absolute lower limit $Q_0 \cong 4.57$ ms of cycle duration (in adults) of which admissible cycles in states of resonance are integer multiples $q = 2^n$ with $n = 1, 2, 3, \cdots$ resulting in organization of quantal epochs $q \times Q_0$ in ranges $R_q$ of multiples $N \times q \times Q_0$ with $1 \leq N \leq$ M and, in most cases, M = $30^5$. The gap to global EEG formations is bridged by two isomorphism assumptions: (A) Every train of $N$ quantal epochs Q corresponds to a compound oscillatory cycle of duration $N \cdot$Q; (B) any uniform segmentation corresponds to a cross-coupling of one oscillation with another oscillation of shorter cycle. There follow exactly four sub-sets of multiples $N$ of Q such that no member of each set can be generated by segmentation of another member: A*: $16 \leq N \leq 30$; B*: $8 \leq N \leq 15$; G1*: $4 \leq N \leq 7$, and G2*: $N = 2, 3$. For Q = $Q_0$, A* proved to be a good predictor of the Alpha Band while the other subsets agree acceptably with the Beta, Gamma1 and Gamma2 bands. Analogously, counterparts of the Theta and Delta bands can be specified by self-similar transformations of $R_1$. The present approach reveals a singular position of Alpha as generator of other frequencies, which may account for familiar empirical peculiarities. Also, frequencies subserving in a certain context a primary generative function may within a different context appear in a secondary, dependent, position. Based on more specific predictions, strong evidence can be provided of a constructive role of transmission delays in avoiding frequency floating and spurious synchronization[4, 5].

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# The "*geometric difference*", a meaningful measure of dissimilarities in psychophysics

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The dissimilarity between stimuli or between performances to compare is commonly assessed by the arithmetic difference $(Au - Bu)$ between their respective measures expressed in some unit $u$ from the *Système international (SI)*, e.g. grams for weight perception, milliseconds for reaction time. However the value $(A - B)u$ alone is a priori less informative than the relative difference that is generally expressed in percent. The relative difference is most often obtained from one of the following ratios: $(A - B)/A$, $(A - B)/B$ or $(A - B)/M$; placed in the denominator, the arbitrary 'standard' value may be the initial one in a change, the larger of the two to compare, or another value in between, such as an average. Choosing one standard provides - or not - access to one or two among three often-desired properties: additivity; symmetry; consistency between values measured in inversely-proportional units (such as frequency in beat per minute and period in milliseconds) $u$ and $v = ku^{-1}$. None of the above options satisfies all three properties:

Symmetry: $\Delta(A; B) = -\Delta(B; A)$.
Additivity "*à la Chasles*": $\Delta(A; B) + \Delta(B; C) = \Delta(A; C)$.
Consistency for inverted units: $|\Delta(A; B)| = |\Delta(kA^{-1}; kB^{-1})|$.

I propose as a value for the relative difference between $A$ and $B$ the difference between their natural logarithms: $Ln(A) - Ln(B) = Ln(A/B)$, that I would call the *geometric difference*. This value always sits between the two extreme estimates $(A - B)/A$ and $(A - B)/B$. This is specific to the natural logarithm (i.e., logarithm to the base $e$) only. As for logarithms to any base, it possesses the three above-mentioned properties. It can be directly expressed in percentage. It is simple to show that it is actually the (arithmetic) mean of all $(A - B)/M$ estimates, the standard $M$ in the denominator ranging from $A$ to $B$.

The geometric difference is extremely easy to compute since the natural logarithm is immediately available from any calculator, spreadsheet or other application. When expressed as a percentage, it appears readily understandable to the layperson. In psychophysics, the geometric difference applies to both stimuli and performances, and neatly complies with Weber–Fechner law of proportionality and with Stevens' power law.

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# It’s about time to perceive, with or without Weber’s glasses

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Approaching sensation scientifically is relatively straightforward. There are physical attributes for stimulating the central nervous system, and there are specific receptors for each sense for translating the physical signals into codes that brain will recognize. When studying time though, it is far from obvious that there are any specific receptors or specific stimuli. Consequently, it becomes important to determine whether psychological time obeys some laws or principles usually reported when other senses are studied.

Many researchers in the field of timing and time perception assume that there is an internal timekeeping process, and this working hypothesis is founded on what is often referred to as the scalar property. This timekeeping process is most often reported to be a pacemaker – counter device: the experience of time is determined by the number of pulses – emitted by the pacemaker – that are accumulated by the counter. The variability associated with the rate of pulses’ emission is reported to be a main source of errors when estimating time. The variability should increase as a function of time in a linear way: that is the scalar property, which corresponds in psychophysics to Weber’s law. The variability to time ratio, or Weber fraction, is supposed to be constant over a wide range of durations. But does Weber’s law really hold for time?

The purpose of this talk is take close look at the Weber fraction for time, more specifically for very brief intervals ($< 2$s). After a general introduction, a series of three recent experiments will be presented[1]. In each experiment, standard values equal 1, 1.3, 1.6 and 1.9 s, and time intervals to be discriminated, reproduced, or categorized are presented with 2, 4, or 6 brief successive auditory signals marking 1, 3, or 5 intervals, respectively. The results demonstrate that the variability to time ratio is not constant across the standard interval conditions; the Weber fraction is indeed higher at 1.9 s than at 1 s. This violation of scalar timing occurs whatever the method used, and does not interact with the number-of-interval variable.

In other portions of the talk, (1) older pieces of the timing literature will be revisited to show that this finding is not unforeseen[2, 3]; (2) drawing on additional data it will be argued that the psychological meaning of this non-constant Weber fraction reflects a fundamental limit – a temporal span – in human information processing; (3) timing data emphasising a multi-modal approach will be presented briefly and (4) there will be some discussion about the impact of this non-constant Weber fraction for time, and of the modality issue, on the single-clock hypothesis and the models of time perception.[4]

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# Selective attention under stress: Evidence from the Stroop effect

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The ability to attend selectively to the task-relevant aspect of the stimulus is crucial for adaptation and survival. Selectivity is most essential when the task is performed under stress entailing problems of adaptation or time constraints. Therefore, it does not come as a real surprise that selectivity improves under stress[1]. The Stroop effect, psychology's "gold standard" of selectivity, was found to be significantly reduced under stress, indicating enhanced selectivity under stress[2]. In our research, we employed the classic color-word Stroop task, testing performance under high- and low-stress. The unique feature of our study was the manipulation of the color-word contingency, produced by the proportion of congruent stimuli in the experimental block. It is well documented that the Stroop effect increases with the proportion of congruent stimuli, an effect attributed to the observer's strategy. Given the word-color contingency, the observer will likely choose to attend the nominally irrelevant dimension in order to maximize performance. Assuming involuntary narrowing of attention under stress, one would expect the contingency effect to desist or to diminish under high stress. We replicated the well known Stroop effect as well as the contingency effect. Moreover, the Stroop effect diminished under high stress. Surprisingly, the size of the contingency effect was fairly consistent across low and high stress. These results indicate that the strategy used was equivalent in both the low and high stress conditions. The observers paid attention to the irrelevant dimension of word under both high and low stress. Therefore, the reduction in the Stroop effect under stress cannot be attributed to improved attention, but must be driven by other factors.

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# Psychophysical training effects on young children with autism

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Psychophysical training is a new approach for engaging and optimizing natural human performance development. The method is based upon the new science of learning which emphasizes the need for building essential neural architecture before traditional learning takes place. If sensory system function such as data detection, integration and coordination are not built properly, clear perceptions for initiating appropriate actions and behavior will be compromised. The method focuses on exercising sensory system function and efficiency of input to output performance. Psychophysical training was initially developed for neurotypical children to provide parents with a comprehensive 'Developmental Wellness' approach to ensure proper development of brain and body function.

The Timberlawn Psychiatric Research Foundation has funded two studies conducted by the Autism Treatment Center in Dallas, Texas studying the impact of psychophysical training on children with autism. The first study was conducted in 2012 and included 17 children with mild to severe symptoms between the ages of 2 and 10 years of age. This study was published by the Yale Journal of Biology and Medicine and demonstrated the feasibility of the training method for children in this population[1]. The greatest impact occurred among the youngest children. A second study was recently completed (June 2014) and results now being analyzed. The second study included 22 one and two year old children identified with autism symptoms. Initially results are positive including at least one child moving off the autism spectrum and others with increased verbal, cognitive and appropriate, efficient behavior output.

Currently one in six children are diagnosed with neurodevelopmental delays. Sensory processing disorders probably associated with inadequate brain region interconnectivity, are common underlying issues for children with autism. Psychophysical training employs a program that exercises each child's unique psychosensory capacity to navigate their visual and neuromuscular fields. This approach strengthens needed sensory system functionality, coordination, and CNS interconnectivity.

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# Time-order effects and generalized subjective magnitude in crossmodal stimulus comparison

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Crossmodal comparability for stimulus magnitudes on modalities lacking a common intensity aspect, such as line length and tone loudness, may rest on a more general magnitude concept.

In a recent study[1], possible time-order error (TOE)-like effects were looked for in crossmodal comparison of successive stimuli. Hellström's[2] sensation-weighting (SW) model was adapted for use as a descriptive and analytical tool. According to this model, the real comparison takes place between two weighted subjective compounds, each built up by the sensation magnitudes of a stimulus (weight $s_1$ or $s_2$) and of its reference level (ReL) (weight $1 - s_1$ or $1 - s_2$).

Intramodally (tone-tone, line-line) and crossmodally (tone-line, line-tone) paired stimuli, with duration 150 ms and ISIs 400 and 2000 ms, were compared for their strength, with the alternatives 1st stronger, 2nd stronger, and equal, yielding scaled subjective difference ($D$) of +100, 0, and -100. The extended SW model, for a pair with a tone followed by a line, is

$$D = k_T[s_1(\Phi_{1T} - \Phi_{0T}) + (1 - s_1)(\Phi_{r1T} - \Phi_{0T})] - k_L[s_2(\Phi_{2L} - \Phi_{0L}) + (1 - s_2)(\Phi_{r2L} - \Phi_{0L})] + b \quad \text{1a}$$

$$= s_1 k_T(\Phi_{1T} - \Phi_{r1T}) - s_2 k_L(\Phi_{2L} - \Phi_{r2L}) + k_T(\Phi_{r1T} - \Phi_{0T}) - k_L(\Phi_{r2L} - \Phi_{0L}) + b, \quad \text{1b}$$

where $\Phi$ is the physical stimulus magnitude on a scale, -4 through +4 for lines as well as tones (90–170 mm, and 74.7–81.1 dB). It was assumed that, within these ranges, $\Phi = k(\Phi - \Phi_0)$, where $\Psi$ is the subjective magnitude and $\Phi_0$ is the $\Phi$ value for $\Psi = 0$. $k$ is a modality-specific scale factor. Subscripts $_T$ and $_L$ indicate tone and line; $_1$ and $_2$ indicate temporal position. $\Phi_r$ is the physical magnitude of the ReL. $b$ is possible bias. The experimental design, varying both stimulus magnitudes, allowed estimation of the relevant model parameters from the data.

Comparing a tone and a line for their "strength" was indeed feasible, yielding weighting effects and TOEs (assessed by mean $D$) resembling those in intramodal comparison. In terms of the SW model, with ISI = 2000 ms $s_1 < s_2$. TOEs were generally more negative with the 2000–ms than with the 200–ms ISI. The results were well accounted for by the SW model.

Eq. 1b implies that the effective subjective magnitude of each paired stimulus is its ReL plus its deviation from the ReL multiplied by $s$. Estimates of $k_T$ and $k_L$ were similar, indicating crossmodally similar ranges of $\Psi$. Based on this and on findings[3,4] that context effects are much stronger crossmodally than intramodally, it may be hypothesized that in crossmodal comparison the $k$ value for each modality becomes inversely related to the range or spread of the sensation magnitudes in the modality. In the SW model (Eq. 1b) this would mean that the stimulus-dependent parts of the compared magnitudes are standardized quantities, like $z$ values. These would be dimensionless, removing the need for an intermodal "currency exchange" and accounting for comparability of subjective magnitudes in very different modalities.

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# The varieties of momentum-like experience

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Cognition and behavior exhibit biases consistent with future expectations, and some of these biases result in momentum-like effects and have been linked with the idea of physical momentum. Such momentum-like effects include representational momentum[1], operational momentum[2], attentional momentum[3], behavioral momentum[4], and psychological momentum[5]. Literatures on these different momentum-like effects have had little contact, and so the purpose here is to examine (a) similarities of different momentum-like effects and (b) whether different momentum-like effects are separate phenomena or result from similar or overlapping mechanisms.

Representational momentum, operational momentum, and attentional momentum appear to reflect similar or overlapping mechanisms based on a perceptual time-scale and involve extrapolation primarily across space (and thus reflect properties of spatial forms of representation). Behavioral momentum and psychological momentum appear to reflect similar or overlapping mechanisms based on a longer time-scale and involve extrapolation primarily across time (and thus suggest previous views of dynamic representation should be extended to include longer durations).

All five forms of momentum-like effect might be unified at the level of computational theory and reflect a general predictive mechanism that involves (a) dynamic representation; (b) extrapolation of actions, behaviors, or outcomes in space and in time; (c) sensitivity to variant and invariant environmental contingences; (d) increases in adaptiveness; (e) bridging a gap within the stimulus or between the stimulus and response; (f) emphasis on subjective aspects of environmental contingencies rather than on objective aspects of those contingencies; (g) insensitivity to irrelevant stimulus-specific characteristics (e.g., surface form); (h) automatic application of the mechanism responsible for momentum-like effects; and (i) cognitively penetrable components and cognitively impenetrable components.

Although it is possible there are separate mechanisms for each stimulus quality that exhibits momentum-like effects, it is more parsimonious to posit a general and abstract high-level process (or small number of such processes) that extrapolates and anticipates actions, behaviors, and outcomes regardless of stimulus-specific features and modality. In this sense, momentum-like effects reflect some of the most useful, general, and ubiquitous adaptations in cognition and behavior.

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# The mind in the cave: perception of paleolithic paintings and petroglyphs

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Ever since the discovery of paleolithic cave paintings at Lascaux, Chauvet, and Altamira, the cognitive capacity of prehistoric humanity has been debated[1]. The representational space of paleolithic artwork has been suggested to produce perceived looming of the depicted images, and this has been suggested to reflect dynamics of perception[2]. This hypothesis was tested in two experiments that presented pictures of cave paintings and petroglyphs.

In Experiments 1 and 2, a target image followed by a probe image was presented. Probes were 10% or 5% smaller than the target (equivalent to a farther viewpoint), the same as the target, or 5% or 10% larger than the target (equivalent to a closer viewpoint). The targets and probes were viewed through a rectangular opening in a black surface centered over the image and that overlapped the edges of the image (and so the perimeter sizes and shapes of targets and probes were constant across all stimuli and trials). Half of the images depicted a frontal view, and half of the images depicted a profile view.

In Experiment 1, participants judged whether the probe was the same as or different from the target. Participants were more likely to respond *same* to smaller probes. Weighted means based on proportions of *same* responses were calculated, and weighted means for frontal views and for profile views were significantly less than zero. In Experiment 2, participants used a -2 (closer than) to +2 (farther than) scale to rate whether the viewpoint for the probe was closer than, the same as, or farther than the viewpoint for the target. For frontal views and for profile views, ratings for the -10% and -5% probes did not differ from zero, and ratings for the 0, +5%, and +10% probes were significantly less than zero (consistent with a remembered smaller size).

In Experiments 1 and 2, memory for the target was displaced away from participants (toward a farther viewpoint). This is consistent with boundary extension, in which memory for a scene is biased to include information that might have been visible just beyond the edges of the scene[3]. The apparent looming effect for paleolithic artwork might involve a two-stage process in which (a) there is boundary extension based on the initial fixation of a given region and (b) subsequent fixation of that region results in a mismatch of previously perceived (displaced) information and currently perceived (not displaced) information. As a consequence, a currently perceived target would appear to be closer than when that target was initially perceived, thus accounting for the perceived looming.

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# Context effects in perception and discrimination of paired bounce heights

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Experimental work examining the role of context in discrimination and comparison of visual magnitudes is fundamental to developing an understanding of how we judge visual magnitudes. Here we examined the influence of surface properties on perception of bounce height using the method of paired comparisons, where time-order effects (TOEs), which is when an observer over- or underestimates the magnitude of one stimulus relative to another in comparison of two stimuli presented sequentially, were analyzed using Hellström's Sensation-Weighting (SW) model[1]. We predicted that the surface visual characteristics on which a ball bounces plays a role in comparison of bounce heights, and that a surface with smooth visual characteristics will afford higher bounce height, than a surface with rough visual characteristics, due to an association between the material qualities, smoothness and hardness. Such an association has been demonstrated before and is thought to arise because materials that have smooth surfaces (e.g. plastic, chrome) are typically denser and subsequently harder than those with rough surfaces (e.g., fabric, sand)[2].

Participants ($N = 62$) observed animations of a ball bouncing on a surface plane with either matte or shiny features. Each trial comprised an animation of two ball bounces in temporal sequence, one with a ball bouncing on a rough plane, and one with a ball bouncing on a smooth plane. The heights of the two bounces in each stimulus pair were varied systematically in semi-factorial combination. The findings include characteristic asymmetries that were found to change systematically in direction and magnitude depending on the surface properties of the plane; bounce height was perceived to be higher for smooth as compared to rough surfaces, for both matte and shiny planes. The relationship between the visual characteristics of the surface plane and bounce height was also studied using a semantic differential scale, where participants rated the surface properties together with various bounce heights in terms of three dimensions: roughness, glossiness, and hardness. In sum, the mean ratings and agreement percentages resemble the weightings revealed by the Hellström's SW model, where mean ratings for hardness decreased (rated harder) in line with increasing bounce height and smooth surfaces were rated harder than rough surfaces.

The results compliment recent views on material perception – that observers have vivid impressions of what is typical for certain materials based on prior associations and such associations are used when comparing and identifying materials[3]. According to the current study, the visual appearance of a surface on which a ball bounces influences the perception and comparison of bounce heights, where smoothness is perceived as a typicality for hard materials that afford higher bounce heights than softer materials.

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# Do NFCS subscores react similarly to physiological indicators under the psychophysical parameters' view point?

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The Neonatal Facial Coding System (NFCS) is a one-dimensional pain assessment tool developed to evaluate the behavioral response of newborn babies to painful events. It is composed of 10 subscores: brow bulge, eye squeeze, nasal-labial furrow, open lips, vertical mouth stretch, horizontal mouth, taught tongue, tongue protrusion, chin quiver and lip purse. An increased score during an event is related to activation of the central nervous system and denotes pain[1]. The psychophysical parameters intensity, reactivity and regulation are used to evaluate the response of physiological measurements to painful stimuli[2]. However, there is only one study relating the Premature Infant Pain Profile (PIPP), and none relating NFCS, to the parameters mentioned above[3].

With the aim to evaluate whether the psychophysical parameters of intensity, reactivity and regulation are achieved in the pain evaluation of newborns using the NFCS and its subscores, forty-one healthy term newborn infants were conveniently sampled whilst being videotaped before, during and after 1 minute and 2 minutes of heel prick blood sampling. The reactivity parameter was calculated by the difference of scores between the periods before and during heel prick for overall NFCS and its subscores. The regulation parameter was calculated by the difference of scores between the periods during and at one and two minutes after heel prick for overall NFCS and its subscores. Non parametric tests were made and $p < .05$ was the level of significance.

Overall NFCS and all its subscores of facial action met the psychophysical parameters of *intensity and reactivity* (all $p < 0.01$). Overall NFCS and the majority of its subscores of facial action met the psychophysical parameter of *regulation* after 1 minute of the heel prick, except tongue protrusion and chin quiver ($p > 0.05$). Two minutes after heel prick, only the tongue protrusion of all subscores and overall NFCS didn't index the *regulation* parameter ($p > 0.05$).

It is concluded that the overall NFCS and the majority of its subscores meet the assumptions of the psychophysical parameters of a physiological measurement, with the exception of tongue protrusion and chin quiver.

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# Perceived exertion and heart rate during long term ergometer work of young and older subjects

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To explore the effect of more frequent but shorter compared to less frequent but longer breaks on physical strain in young and older men, 29 participants aged between 27 and 41, 42 to 56, and 57 to 71 years took part in experiments working on a bicycle ergometer. In a preliminary test designed to estimate the individual exercise capacity, participants cycled for 28 minutes at systematically varied loads between 25 and 175 Watt while heart rate (HR) was recorded and perceived exertion (PE) was scaled using the Category Partitioning procedure (CP). The results are well in line with previous findings[1]. In two subsequent sessions with different activity-rest schedules they again cycled for 7 hours each at low to medium load (CP = 20), interrupted by brief peak loads at high to very high exertion levels (CP = 40) as individually ascertained from the exertion functions obtained with the preliminary tests. Cycling speed was always kept constant at 60 rotations per minute. Average loads in different age-groups (continuous load /peak load) were 84/192 watt for the younger, 79/162 watt for the middle aged cohort and 55/137 watt for the older participants.

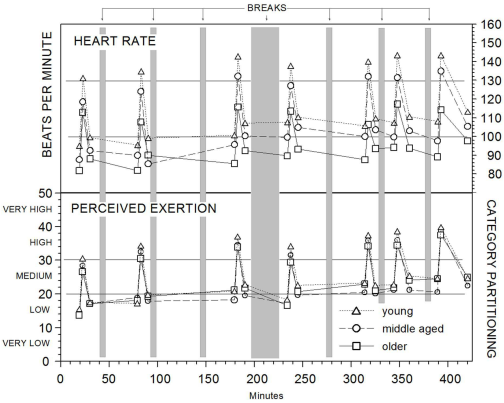

Figure 1: PE and HR for 3 age groups in 7-hours-cycling

As shown in Figure 1 for the frequent brake condition, the continuously raising PE is of about the same magnitude in all age groups for the time course of the experiment, regardless of the differing workloads. The also increasing HR, however is significantly higher in the younger cohorts. The correlation between PE and HR is $r = 0.77$. Fatigue, measured by the ASTS mood scale[2], significantly increased during the time course of the experiment from low to medium, with lower however not significant increase for the older cohort.

In the preliminary test HR and load (Watt) correlate higher ($r = 0.992$) than PE and load ($r = 0.951$) and PE and HR ( $r = 0.963$). Overall results show neither general nor age-related break effects at subjectively equal straining load and indicate that older subjects are not restricted in work performance if the perceived exertion is similar to the PE of younger subjects.

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# Quantified selves: mobile monitoring of pain perception for life enhancement

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Smart phones and wearable devices are everywhere. They provide an unparalleled opportunity to monitor the causes of pain and the effect of therapeutic interventions. Making best use of these opportunities presents fascinating challenges for the psychophysical measurement of pain itself and of its correlates and causes. The quantified-self movement is currently investigating these challenges and opportunities.

*Measurement of Pain and Negative Emotions*

Pain and negative emotions are the key response variables. Borg scales[1, 2] are probably the most widely used for pain and exertion, and for good reason. The 10-point scale should be sufficient for mobile devices and can be used either as a number or a slider. By contrast, negative emotions (depression and anxiety) are typically measured with 5 or 7-point Likert scales. Key issue.

- Are Likert scales sufficient for numerical modelling?

*Measurement of Predictor Variables*

Wellbeing has the potential to be enhanced by identifying and modelling the effect of predictor variables. These may be external circumstances, e.g., rheumatism worse when barometer drops, head hurts after alcohol; deliberate intervention, e.g., breathe deeply, meditate, take the pills. Physical activity, measured by accelerometers or GPS; physiological variables such as heart rate, and EEG; and mood and activity variables are also potential predictors. Some variables (activity, physiology) may be measured passively in the background; other such as mood require active recording.

*How and When to Measure*

Some measuring devices are smart phones with added Apps; others are special fitness or medical devices. Smart phone Apps including: ‘Mapmyrun’, ‘Ithlete’, ‘Mappiness’ are discussed to illustrate the potential and challenges. Key issues.

- Push or pull. Should user be reminded to record at regular intervals, or should the user choose their own time to record?
- Does the very act of recording improve wellbeing?
- How about sharing Facebook? Twitter? Medical professionals?

*Enhancing Wellbeing*

Overarching challenge:

- Identify the most powerful predictors of wellbeing and their interactions

Wish. New devices herald new and fruitful avenues for psychophysical measurement.

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# Proprioceptive performance of the hands in Cartesian space

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Given the morphology of the shoulder joint, the combination of the shoulder and elbow joints allows a high level of capability for transport of the human hand in three dimensions, in order to reach locations and to pick up and manipulate objects[1]. Although previous work has examined the proprioceptive ability of the ankle in two planes, testing both dorsiflexion-plantarflexion and inversion-eversion[2], proprioceptive performance of the hands has been investigated almost exclusively in the horizontal plane[3].

Work by Goble suggests that the two hands become specialized at different tasks through extensive use[3]. Because the left hand of right-handers is used for object placement and stabilization, it develops superior proprioceptive capability, as compared to using the visual feedback control needed for fine manipulation, for which the right hand becomes specialized. Accordingly, it can be predicted that, for proprioceptive tasks performed without the aid of vision, left hand over right hand performance superiority would be expected.

In the current study, proprioceptive discrimination ability of both right (preferred) and left (non-preferred) hand movements was assessed in the medio-lateral, antero-posterior, and superior-inferior directions. A linear apparatus was used to randomly present one of two movement extents: 21.9 cm (short) and 22.9 cm (long) that were judged without the aid of vision. Participants classified each movement using one of four responses: 'Certain-Short', 'Uncertain-Short', 'Uncertain-Long' and 'Certain-Long'. The area under the resulting receiver operating characteristic curve (ROC) was used as the measure of proprioceptive acuity.

A significant interaction showed superior performance for the right (preferred) hand for the two directions in the horizontal plane (medio-lateral and antero-posterior) but superiority for the left (non-preferred) hand in the vertical direction (superior-inferior) with $F_{(1,11)} = 14.29, p = .003, \eta^2 = .57$, suggesting that use of the two hands for proprioceptive tasks without vision is plane-specific - i.e., the right hand becomes practised for movement tasks in the horizontal plane, (e.g., using a computer mouse), and the left hand for movement tasks in the vertical plane. Such asymmetries in hand performance can be seen as reflecting side-dependent task specificity and neuroplasticity regarding proprioceptive performance for right-handed individuals[4].

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# Applications of Bayesian graphical modeling to psychophysics

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A basic scientific challenge in all of the empirical sciences is bringing models and data together in useful ways. Models are often the formal expressions of theory, and data measure the phenomena the models aim to describe, understand, and predict. The success of developing theories and building models on the one hand, and collecting laboratory and field data on the other, depends on the quality of the methods for statistical inference used to bring them together.

This talk discusses a Bayesian approach to analyzing psychological models and data[1]. In particular, we introduce graphical models as a natural and powerful formalism for implementing psychological models so that they are amenable to Bayesian inference. In graphical models, nodes represent psychological parameters and data, and the graph structure represents the modeling assumptions about how the parameters generate the data. Expressed in this way, it is possible to do fully Bayesian inference using modern computational sampling methods through standard software packages like WinBUGS and JAGS.

To demonstrate the potential of this approach, we consider a number of psychophysical applications, involving estimating psychophysical functions from decision-making and response time behavioral data in time perception[2] and brightness discrimination[3,4] tasks. These applications make clear a basic advantage of Bayesian inference, which is the coherent representation of uncertainty throughout the analysis, using probability distributions to quantify what is and is not known about parameters and data.

The applications also make clear a second advantage of Bayesian methods that will be the main focus of the talk. Graphical modeling makes it easy to implement hierarchical (multi-level) model structures, latent mixture model structures, and a range of other statistical and modeling assumptions, without losing the ability to perform fully Bayesian inference. This flexibility is extremely useful for accommodating individual differences, identifying contaminant trials, generalizing predictions to new experimental tasks, and a range of other important goals in psychophysical modeling, and cognitive modeling more generally. We demonstrate these features in the applications, showing how Bayesian methods afford theorists the scope to develop and evaluate richer theories. On this basis, we argue Bayesian methods have the potential to help broaden and deepen our understanding of psychology.

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# Differences in the integration of audiovisual speech versus non-speech signals

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Audiovisual integration studies have used measures that compare processing speed qua efficiency against the statistical benchmark of 'parallel independent race models'[1]. Here, we investigate how listeners may adopt unique speed-accuracy strategies when integrating speech stimuli versus non-speech stimuli. The experiment provided a novel control for speech using a sine-wave signal for auditory speech, and 'point-light displays' for visual speech cues (dots highlighting a talker's points of articulation). Crucially, the speech and non-speech conditions shared identical physical characteristics – the stimuli may be perceived as speech or non-speech (i.e., 'beeps' and 'moving green dots') depending on the context. This allowed us to investigate whether speech integration is "special". The experiment presented a group of four listeners with auditory (sine-wave), visual (point-light), and audiovisual consonants – "b" and "g". The audiovisual condition consisted of a full factorial design: A/b/+Vb ('ba'), A/b/+Vg ('da'), A/g/+Vb ('bga'), and A/g/+Vg ('ga'). On Day 1, listeners were instructed to categorize auditory beeps and visual dots into categories "1" versus "2" in the uni-sensory trial-block. In the audiovisual block, participants were informed that each auditory beep forms a pair with one of the visual patterns (e.g., '11'), and that incongruent pairs would also be presented (e.g., '12'). Listeners were required to respond by pressing a button corresponding to one of the four categories: "11", "12", "21", or "22". On Day 2, listeners performed the same task. However, they were now informed that category "1" was the consonant "b" and category "2" was "g". On uni-sensory trials, response categories were relabeled "b" and "g", while on audiovisual trials response buttons were relabeled "bb", "bg", "gb" and "gg".

Capacity was computed using an AND decision rule for both congruent (e.g., '11', 'bb') and incongruent trials (e.g., '12', 'bg'). Results demonstrated that mean capacity, in terms of both speed and accuracy $(A(t))^2$, was *greater* for congruent trials. Most relevant, this 'congruency gain' was greater for the speech condition. This effect was driven by speed, since decomposed RT-only capacity $(C(t))^2$ was significant, although the interaction for accuracy was not. Our results indicate that speech integration is "special" in the sense that top-down mechanisms inhibit incongruent speech more than non-speech.

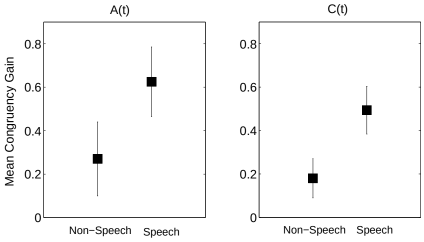

Figure 1: Congruency gain for non-speech and speech trials (error bars indicate one SE)

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# Theory of ideals and its application

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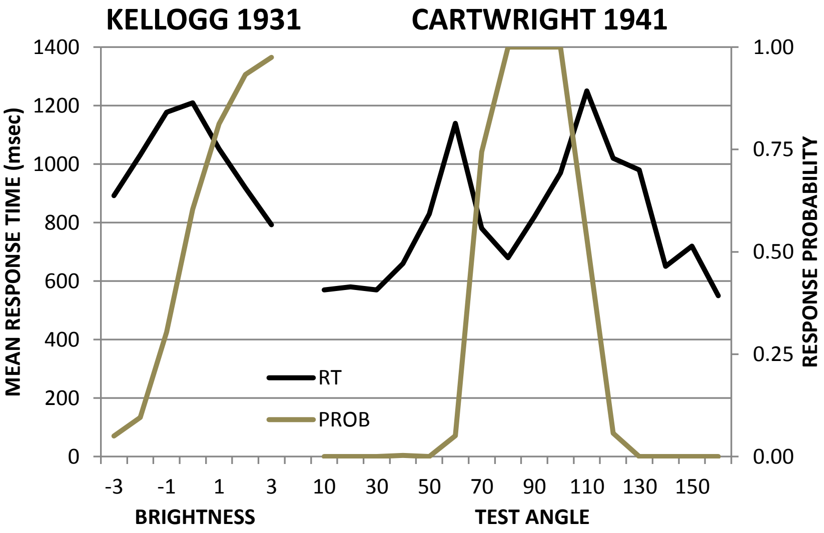
Among the many disturbing examples of statistical psychological data analysis is the lack of understanding of comparative judgment. There are two kinds of comparative judgment. The first is due to Fechner and is known today as Signal Detection Theory. The second is due to Clyde Coombs and is known as Ideal Theory. Many experimenters are unaware that these different comparative judgments produce different response time and response probability results As a consequence they apply routine, inappropriate, statistical analyses to the analysis of their data.

Figure 1 illustrates results from these two different types of judgment. On the left is the classical comparative judgment when one stimulus is compared against another or a Standard the classic Fechner, Thurstone, Signal Detection type experiment. The illustrated psychometric function for “Greater” judgments and mean response times are characteristic of this form of judgment. On the right are the psychometric function for judgments against an Ideal and the mean response times. The problem is that experimenters often do not know that their subjects are comparing two stimuli against an Ideal and choosing the one nearest the Ideal versus comparing the two stimuli against each other. Not knowing which kind of judgment is being made by the subjects leads to errors in interpreting experimental results.

This presentation reviews studies in which subjects compare a stimulus against a standard, a stimulus against an Ideal, or two stimuli against an Ideal. Notice that depending on which type of judgment occurs the mean response time near the center of the range of stimuli will be either very large or quite small. Not knowing which type of judgment occurred leads to obvious errors in interpreting the reason for the obtained results. Such difficulties in interpretation are often found in judgments of preference.



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# Gassendi, the sun, and the apparent size

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Pierre Gassendi, French philosopher, mathematician, and astronomer, played a central role in the scientific revolution, in the first half of the XVI Century. He was a "proto-empiricist" as well as a "proto-mechanicist", and a fierce adversary of the Aristotelianism and of the rationalism, in particular in Descartes' version. A Skeptical philosopher deeply influenced by Sextus Empiricus and by Epicurus, he was a strong supporter of the atomism. His work is still a source of interest among philosophers and historians of the ideas, he was almost completely forgotten by the historians of psychology – the rare references to him in the textbooks are almost exclusively related to his controversy with Descartes, a very secondary aspect of his contribution to psychology. Pierre Gassendi[1], to explain the illusion of the sun at the horizon, advocated mainly the influence of the dilatation of the pupil, a theory that Leonardo da Vinci had supported a century before[2]. His theory, supported in France by his acolytes and very popular till the end of the XVII Century, emerged in four letters to Naudèe, Licetus, Boulliau and Chapelain, written between 1636 and 1640[3]. Anyway, it received little audience out of his circle, and was criticized early by Molyneaux;[4] Diderot, and D'Alembert[5] were ironic about it, and Porterfield[6] spoke of "so very gross an error". Unfortunately, this aspect of Gassendi's theory has completely concealed his contribution to the problem of size-distance invariance. In this respect, his analysis is subtle and sound as the ones elaborated in the same years by Descartes, and few decades after by Malebranche; however, in Gassendi we find a strong emphasis on the role of the senses and of the previous experience. According to Gassendi, the apparent size is not only a matter of sense organs, but also of higher cognitive processes. Two are the aspects to stress here: the previous knowledge of the size of the objects to judge, and the interposition of objects. In his posthumous *Syntagma*[7], he advocates first the factor of the interposition to explain the moon illusion, and only in second instance the dilatation of the pupil and the refraction.

Here, the aim is to re-evaluate this neglected aspect of his work.

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# Individual differences in the production effect in memory

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Words read aloud are better remembered relative to silently read words. This phenomenon is called the production effect (PE). In recent years, the definition of the PE was widened to other types of production[1] (writing, mouthing, typing, singing, etc.). Despite the consistent evidence, the PE is mainly[2] found in mixed lists (in which half of the study words are read aloud, and half are read silently), and its source is not fully clear.

There are two competing theories explaining the PE. According to the distinctiveness account[3,4], vocally producing a word enhances its memory trace relative to non-produced word (silently read) as it involves a greater number of unique encoding processes. A different theoretical view[5] suggests that the PE reflects a cost (inferior memory) to silently read words rather than a benefit (superior memory) for vocally produced words. Possibly, the silent items suffer a cost because the aloud items disrupts their encoding. This cost may reflect shallow processing of silent words.

In the current work we review 16 PE experiments conducted in our lab during the past year. In this review we explore the data at the individual level rather than in terms of overall means. The main conclusion of such analysis is that the PE is indeed a steady phenomenon. Despite variations between experiments (e.g., modality, stimuli, and participants), they all suggest a memory advantage in favor of the produced words (e.g., words spoken aloud). However, the results also indicate that a noteworthy number of participants show no PE and even a reversed PE.

Using a meta-analysis we show that participants with a positive PE did not differ in overall remembered words from participants with negative (or no) PE. Specifically, the 'vocal advantage' did not yield any overall benefit in memory for participants with PE relative to participants without PE. Hence, the enhancement in memory for aloud words is due to a toll taken on the non-produced words. In conclusion we argue that the source of the PE in memory is actually detraction in memory for silent words rather than advantage for the vocally produced words. This result provides a strong support for the cost account over the distinctiveness account.

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# Distance is not objective: Distance differences between and within objects

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High-level visual functions depend on one's ability to parse and organize the visual field into meaningful structural representations, e.g., objects and groups[1]. Given their fundamental role in cognitive processes objects have been the subject of studies since the early days of scientific psychology[2]. The current study examines how objects affect spatial processing. Specifically, is the distance between two separated objects perceived different than the same distance within the same object?

In the current study participants were asked to estimate the distance between two dots. In the within-object condition, the two dots were located within a single circle. In the between-objects condition, each dot was located in a different circle. Distances between two dots inside the same object were estimated significantly smaller than distances between equivalently spaced dots inside two separate objects. The psychophysical power functions[3] for between- vs. within-objects distances were: (1) $y = 0.8124x^{1.0429}$ and (2) $y = 0.7042x^{1.0971}$, respectively. As can be seen, for both conditions, the value of the exponent (b) was proximately 1, with no significant difference. However, the measure constant was significantly smaller for distances within the same object. Similar effects are obtained in monaural vs. binaural loudness perception and the perception of effort or exertion, indicating proportional differences in perceptual processing[4].

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# Reappraisal of magnitude estimation as an adjunct method for functional measurement

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Functional rating is an adequate adjunct method for functional measurement[1]. While some data show that magnitude estimation is also adequate for this purpose[2] some other data show that it is inadequate[3]. An experiment was conducted to further explore this issue.

Stimuli were pairs of 10-cm square cardboards covered with sandpaper. One sandpaper of each pair was presented to the subject's left hand and the other to the subject's right hand. For each stimulus, a different combination of mean sizes of the sandpaper grains 26, 58, 201, or 425 µm was used. Subjects were asked to gently rub the sandpapers of the presented stimuli simultaneously with their preferred fingers and to judge the amount of friction that occurred between these sandpapers in the event that the sandpapers were sliding one over the other.

Twelve subjects participated in two consecutive sessions. The first session was a magnitude estimation session. A stimulus with sandpapers with grain size of 125 µm defined the standard friction with modulus of 20. The second session was a functional rating session. Subjects rated the amount of friction between the sandpapers of the stimuli on a 0–100 scale with "100" defined by an anchor stimulus with sandpapers with grain size of 538 µm and "0" defined by an anchor stimulus with smooth surfaces in place of the sandpapers.

Table 1: *Mean judged amount of friction.*

| | MAGNITUDE ESTIMATION | | | | FUNCTIONAL RATING | | | |
|---|---|---|---|---|---|---|---|---|
| | Right Grain Size (µm) | | | | Right Grain Size (µm) | | | |
| Left Grain Size (µm) | 425 | 201 | 58 | 26 | 425 | 201 | 58 | 26 |
| 425 | 40.8 | 34.3 | 27.7 | 20.8 | 50.8 | 43.1 | 37.5 | 35.5 |
| 201 | 35.0 | 30.3 | 19.6 | 14.5 | 47.9 | 33.5 | 28.4 | 22.9 |
| 58 | 27.3 | 21.3 | 11.5 | 9.9 | 40.0 | 22.8 | 19.2 | 12.8 |
| 26 | 21.0 | 15.3 | 9.8 | 6.3 | 33.5 | 22.7 | 14.1 | 9.0 |

Table 1 reports the results. The effects of factors were significant and the interactions not significant [*magnitude estimation*: $F_{(3,33)} = 52.5$, $F_{(3,33)} = 64.4$, $p < .001$, and $F_{(9,99)} = 1.9$ with $\eta_p^2$ of 0.83, 0.85, and 0.15, respectively; *functional rating*: $F_{(3,33)} = 56.4$, $F_{(3,33)} = 46.8$, $p < .001$, and $F_{(9,99)} = 1.4$ with $\eta_p^2$ of 0.84, 0.81, and 0.11, respectively]. The nonsignificant interactions indicate that magnitude estimation and functional rating were statistically equivalent adjunct methods. Disagreement of these results with prior results[3] may be due to the choice of the standard which may make magnitude estimates nonlinear[4, 5].

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# A mathematical model to explain the quantity of Velvet Hand Illusion

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You can easily experience the Velvet Hand Illusion (VHI) if you place two fixed rods between your hands and move the hands simultaneously in an orthogonal direction against the rods. The purpose of the study was to propose a mathematical model to explain the amount of VHI experienced. Magnitude-estimation-experiment data (the diamonds in Fig. 1) were used for the curve fitting.

From the experimental data, we inferred the following hypotheses:
(1) When you touch both rods with your hands simultaneously and move your hands enough, you feel the VHI. As the distance between the rods becomes larger and the moving length shortens, the illusion amount decreases. If the distance is too large to touch the both rods simultaneously, you feel no VHI.
(2) When the distance between the two rods is short, the impression given by the rods is strong and it masks the VHI. Along with an increment in distance, the amount of illusion experienced becomes larger.

The condition (1) is shown as

$$f_1(x) = \frac{\exp\{-a(x-b)\}}{1+\exp\{-a(x-b)\}} \qquad (a>0, b>0).$$

And the condition (2) is shown as

$$f_2(x) = 1-\exp(-cx) \qquad (c>0).$$

The total amount of the VHI is shown as

$$f_{VHI}(x) = df_1(x)f_2(x) = d\frac{\exp\{-a(x-b)\}\{1-\exp(-cx)\}}{1+\exp\{-a(x-b)\}},$$

where the $d$ is a parameter determined depending on the unit of measurement. The fitted equation to the magnitude-estimation data is shown as the thick gray line in Fig. 1.

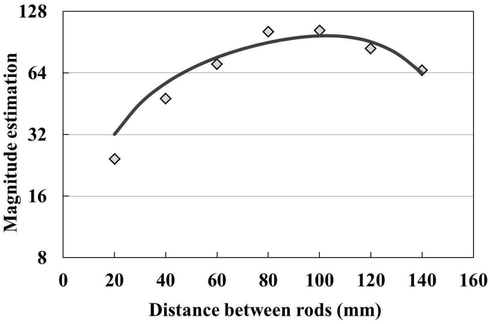

Figure 1: Each Diamond shows a level of the VHI measured by the magnitude-estimation method.

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# Learning mental rotation

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Measured gender differences in cognitive abilities appear to have diminished over time[1], but mental rotation continues to yield large, statistical differences favoring men. In addition to the biological differences, there are experiential differences between genders. 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.

Forty-four women completed six sessions of practice with figures different from MRT figures. Subsequently, they took the Revised Mental Rotations Test (RMRT)[3]. Their scores, the number of items for which both target rotations were marked, were nominally higher than a control group of unpracticed men. Practice materials were derived from three sets of MRT-like figures, each with an additional feature. Each item included a target, a picture plane and a depth rotation of the target, a rotated mirror image, and a structurally different figure. Practice sets 1, 3, and 5 were the three original sets. Sets 2, 4, and 6 were constructed by randomizing the order of the items, changing the target, and randomizing the order of the figures in the items. RMRT items contain both mirror image and structurally different figures but rarely (2 of 24) both in the same item.

Correct responses to figures increased during practice and increased slightly during the RMRT. The number of incorrect responses increased irregularly until the last practice and decreased significantly during the RMRT. The number of blank responses decreased during practice and increased considerably during the RMRT. Standard scores increased non-monotonically by half again from the first to last practice, from 6 to 9 and by $1/3$ again during the RMRT to 12. d' values increased from first to last practice by $2/3$, from .6 to 1, and by more than twice, to 2.5, during the RMRT. Standard scoring treats both unmarked correct figures and incorrect markings as the same category, errors, whereas signal detection treats unmarked correct figures as misses, and incorrect markings as false alarms, i.e. different classes of error with different effects on measured discriminability.

The real effect of using standard scores is to emphasize decision making speed over discriminability, whereas with signal detection, discriminability is emphasized over decision making speed. The effect of practice was to increase women's ability to discriminate rotations of a target from mirror images and structurally different figures without maximizing speed. Training to increase discrimination speed might improve women's spatial ability, as measured by the RMRT, above men's.

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# Putting feelings into psychophysics: Theodor Lipps (1905) on the perception of weight and other modalities

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In 1894, Theodor Lipps was offered the Chair of Psychology at Munich, where he stayed until his death in 1910. Here, he prepared a second edition of his *Psychologische Studien*[1], a treatise on visual perception and music perception originally published in 1885, when he had taught at Bonn. The second edition, however, contained a new article entitled "The law of psychic relativity and Webers Law." Lipps is better known now for having promulgated the notion that some geometric–optical illusions result from *Einfühlung* (empathy). His article on Weber's law does not mention empathy but does assert that judgments about sensation-intensity discrimination reflect the contents of a participant's consciousness, and that these contents are determined by the activity of "apperception." These judgements fell into two categories.

In the first category, a judgment was made that an increase in sensation intensity had occurred; but this judgment also specified the amount by which the sensation intensity had increased. Lipps's examples concerned line–length discriminations, which involved "extensive" measurement units, such as millimetres. In the second category, a judgment was restricted to whether an increase had taken place; no reference was made to the amount *by* which the intensity of the sensation had increased. In many cases, a reference to that amount would be unfeasible because the units of measurement are hard to provide for "intensive" dimensions, which include sensation intensities. In these cases, the sensation-with-an-increment was viewed as a whole that could not be *physically* divided into equal-sized units of measurement. But, using the apperceptive mechanisms determining the contents of consciousness, the sensation–with–an–increment could be *psychologically* divided into an (imagined) original sensation and a separate (imagined) increment. An important property of the whole sensation-with-an-increment was that, the larger the increment, the more numerous the positions (e.g., spatial) in that sensation–with–an–increment; but the amount of attention that would be attracted to each one of these (imagined) positions would be diminished.

Tasks involving the selection of an intensity intermediate between a lower and a higher intensity, because they involved judging the amounts *by* which the intermediate intensity differed from the other two, exemplified the first category of judgments. Tasks involving judgments of sensation-intensity discrimination alone *might* include judgments of heaviness, where Lipps claimed that the "activity of apprehension" associated with judgements about sensations would be replaced by an "activity of the will" associated with movements. Nevertheless, the size-weight illusion and the influence of *Einstellung* (set) upon consecutive judgments of heaviness were both asserted to involve "ulterior psychological processes" rather than just psychophysical ones.

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# Measurement-theoretic and philosophic foundations of Stevens' power law

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There are many approaches for describing the compatibility of physics and psychology in psychophysics. In the 1940s and 50s, S. S. Stevens developed a theory of measurement that was radical for its time, and applied it to psychophysical measurements. He demonstrated empirically that the power law describes this compatibility. However, both from classical and modern perspectives, his theory of measurement lacked an adequate foundation, had serious gaps, and contained misconceptions about the nature of numbers and their role in science. Nevertheless, as this presentation will show, many of his insights into measurement were essentially correct.

Historically, psychophysics has proceeded by first producing a mathematical representation of physical phenomena, and then representing psychological phenomena in terms of it. This raised the issue of separating out in the mathematical-physical-psychological representation, exactly those phenomena that had real psychological significance from those for being a result of physical measurement or its conventions. Today, this is described as a meaningfulness issue, which is a generalization and is historically linked to a related concept introduced into science by Stevens in the statistical part of his theory of measurement. It will be argued that the exponent in Stevens' Law does not correspond to any purely psychological phenomenon, but is based, in part, on a particular convention of physical measurement.

The power law is a psychophysical law. But what makes it a "law" as opposed to just a valid description of a general and repeatable psychophysical phenomenon? A qualitative axiomatization of the power law will be presented, and it will be shown that it codes a deeper level of invariance than ordinary valid psychophysical relationships. In his theories of measurement, Stevens used an empirical approach to numbers and their use in science. A formulation of "number" based on Stevens' insight will be given that is based on concepts from modern measurement theory.

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# Neural substrate analysis for visual motion perception and subjective timing

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Visual artworks can be studied according to different cognitive appraisals such as the implied human body movement representation. Pictures of ballerina sculptures of different classical ballet postures by impressionist Edgar Degas modulated time perception: the greater the body movement in a static image, the longer the time perceived[1]. Probably, these time distortions were related to mirror-neurons activation by embodiment mechanisms since imperceptible different body oscillations were recorded when the subjects observed these images and estimated their time duration[2,3]. This study carried out MRI-analyses searching neural substrates for both visual motion perception and subjective time. Stimuli were the same static images of Degas ballerinas of the Body Movement Ranking Scale[1] used previously with the values 1.5, 3.0, and 6.0 points. Each undergraduate participant (12 men and 11 women) observed only one stimulus lasting 27 s and then reproduced its time duration (four times) through the prospective paradigm (reproduction method). This task was performed inside the MRI scanner.

Data analyses revealed that the stimuli were underestimated in relation to the actual exposure (27 s). Also, the 1.5-point stimulus (less movement) was estimated shorter than the 6.0-point stimulus (more movement) corroborating the data of previous studies. Agreeing with researchers that used real pictures of humans performing actions[4], the MRI-analyses revealed different activations of MT/V5 cortical brain areas in both hemispheres which were obtained according to the movement score increasing of ballerinas' images (1.5 to 6.0 points). Moreover, the cerebellum and the frontal cortical brain areas (BA6 and BA9) were more activated for the 3.0- and 6.0-point stimuli. Neural activation was less during the time-estimation task than during the image-observation task, probably because of the different strategies used by participants while estimating time. Moreover, the MRI-analyses for time estimation showed that the cerebellum, the BA39, and the BA40 cortical areas were more activated for 6.0-point stimulus. Differential neural activation of the brain areas allows us to point out that different processes are involved in both motion and time perception when people observe human body movements in static images.

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# The challenge of pain

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Treating pain is a complex and stressful task that requires consideration of the type of pain that the patient experiences and the motivational, cognitive, emotional, and personality characteristics of the individual who suffers from pain. Fundamental information about the choice of effective, tolerable, and safe treatment reveals how difficult it will be for healthcare professionals to relieve pain in affected individuals[1]. As a subjective experience, pain requires different mechanisms of interpretation which can be physiological such as the result of an injury, or psychological, such as the anticipation of an injury. Although one might be able to differentiate purely physiological aspects from psychological aspects at the experimental level, the same does not necessarily hold true at the interpersonal level when working with patients who are in pain. In the latter case, these two dimensions are deeply connected. Such subjectivity is also manifested in different cultures with regard to pain perception and expression. Descriptors of pain also vary, positioning themselves in different perspectives, such as sensorial-discriminative, motivational-affective, cognitive-behavioral, and nociceptive[2].

Each patient represents a unique and genuine case for whom physiological, emotional, and cognitive aspects are components of pain perception. This fact requires that we must consider multiple factors, from knowledge of the neurophysiological mechanisms of pain to understanding the emotional and attentive factors that modulate pain perception and its expression[2]. In this context, pain measurement remains a great issue. Pain assessment constitutes a cornerstone of its treatment[3]. Without a proper evaluation, clinicians cannot determine whether the intervention is effective. Therefore, reliable and valid pain measurements are critical for understanding the effectiveness of painkillers and other treatments in clinical practice. Just because pain assessment is necessary for its effective treatment, everything that contributes to the knowledge of its measurements also contributes to pain reduction and the relief of pain-induced suffering. One cannot base the efficiency of a new therapeutic approach on only the clinician's perception of whether the approach is satisfactory for proper pain control[3]. To better understand the phenomenon and evaluate the efficacy and tolerability of interventions, using more sophisticated pain measurements to assess intensity and cognitive and affective responses linked to pain, becomes indeed necessary[4].

Understanding this subjectivity is our great challenge, especially knowing how to measure and evaluate pain, regardless of whether the pain is our own or the pain is of others[5].

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# Empirically driven improvement of the linearity of extant faces pain scales

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Understanding whether a score difference obtained on a pain scale expresses a clinically significant change is an important practical issue. For children in the range of 8 to 15 years old, a 10 to 20% change in a VAS scale was suggested as the minimum clinically significant difference (MCSD)[1]. Transposed to faces scales composed of 6 expressions (e.g., the FPS-R[2] or the FACES[3]) and assuming equidistance, a one-face change would thus meet the MCSD criterion. Unfortunately, as this assumption remains untested, a one-face change may have a variable meaning in different parts of the scale[4]. Equidistance between faces isn't actually required for expressing clinical significance as a percentage of the scale range: suffice that expressions be measured on an interval level (linear) scale. It is nonetheless important for the probing of pain intensity along its range of variation, and for supporting scoring on a 0-10 format with equal steps of 2.

Two sorts of studies were conducted with the FPS-R and the FACES, using functional measurement[5]. The two scales were first taken as factors and their faces fully combined in an integration task. Two groups of children (6-8 and 9-11 years old) evaluated the overall pain conveyed by each pair of faces. Results were consistent with an averaging integration rule, from which independent estimates of weights and scale values were derived for each face via functional measurement. The latter were given at the interval level, revealing marked unequal spacing between faces in both scales. Moreover, the structure of deviations from equidistance was replicated in both groups, suggesting that it is stable. Secondly, separate integration experiments were performed for each scale, using as factors the upper- and lower-face features of the pain expressions (participants judged the 36 faces arising out of the factors combination as to conveyed pain; two groups of children differing in age performed on each task). An averaging rule was also found, which provided interval scales of the upper (in the region of the eyes / eyebrows) and lower (in the region of the mouth) face components. When entered into the obtained averaging model, these functional values could predict the deviations from equidistance previously found with the overall faces. These results make possible: (1) to implement as of now an MCSD criterion of 20% of the scale range in the FPS-R and the FACES; (2) to strive for improvements of the linearity (equal intervals) property of those scales via an analytically-guided graphic alteration of their inner features.

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# Simultaneous timing: differential attentional processes and auditory dominance

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Assuming that accurate time estimation requires attention, timing two simultaneous intervals should involve sharing attention between both estimations. As attention may be conceived as a limited resource, timing two intervals would lead to a division of attention, resulting in a decrement in performance[1]. The present study used a task implying to produce two partially overlapping intervals. One objective was to test whether the attentional cost increases with increasing duration of overlap. Another objective was to determine whether the cost would be similar for both intervals, which would suggest similar underlying processes in producing both estimates. Many studies report higher timing accuracy when the stimulus to be timed is auditory rather than visual[2]. A final objective was to determine whether the modality of an interval would influence the estimation of another, partially concurrent interval.

In Experiments 1 and 2, 28 and 29 participants respectively were trained to produce a 2500-ms target interval. Then, in each experimental trial, the task was to produce two partially overlapping target intervals, a first and a second time production (TP). Participants initiated the first production, but the location of the signal indicating the beginning of the second interval varied between trials (750, 1250 or 1750 ms after the beginning of the first TP). In Experiment 2, a condition was added: in some trials, the signal beginning the second interval did not occur. These trials were interspersed randomly among experimental trials so that their occurrence was unpredictable. Modality (Auditory or Visual) of the signals presented during the first and second intervals varied between trials. Every combination of modalities (A-A, A-V, V-A, V-V) was tested in both experiments.

Results show that the second TP was longer as the duration of overlap between the productions increased, suggesting an effect of attention sharing. Results of Experiment 1 also showed an expectancy effect: analyses on first TPs revealed that they lengthened with later occurrence of the signal beginning the second interval. This interpretation was supported in Experiment 2 as trials without second productions led to longest TPs. Those results suggest the involvement of different attentional processes in partially simultaneous time productions.

Modality of the first interval influenced the second TP, which was shorter with an auditory than with a visual first interval, an effect obtained only when the second TP was auditory. These results suggest auditory dominance in temporal processing, as it seems easier to estimate two intervals if both are in the auditory modality.

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# On the magnitude of the placebo effect for pain

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The placebo effect on pain occurs in subjects who are untruthfully told that they have been modified (e.g., drugged) so that painful stimuli will hurt less than they ordinarily would. Stimuli are rated as less painful after these instructions than they had been previously. None of the large literature on this topic explicitly investigates the perceptual magnitude of the effect – how much less painful the placebo effect has made a stimulus. We will focus here on studies using thermal pain that provide some suggestions about perceptual magnitude.

Investigators measure placebo effects using shifts in ratings of the painfulness of hot stimuli from ratings in some baseline condition to ratings after placebo application. Most studies use a 0 to 10 or 1 to 10 numerical rating scale where 1 = "just painful" or "threshold" and 10 = "unbearable" or "most intense pain imaginable". Reported placebo-induced reductions in mean pain ratings range from about 5.75 to 4.5[1], to no effect on pain intensity ratings[2] (but a reduction in ratings of pain unpleasantness from 3.45 to 2.61.) Studies using a 0 – 100 mm visual analogue scale (VAS), have graphed reductions in pain intensity ratings ranging from (estimated) 59 mm to 37 mm[3] and from (estimated) 57 mm to 49 mm[4].

So how much pain reduction is that? The two studies using the VAS report average rating reductions of 22 mm[3] and 8mm[4]. Some studies have investigated the psychophysical function relating temperature to 100-mm VAS pain intensity ratings. They have reported that a change of 1 °C alters ratings by about 12 mm[5], by about 12.5 mm[6] and by about 26.5 mm[7]. That suggests that the magnitude of the placebo effect on the pain intensity of hot stimuli is a reduction of about 1 – 2 °C. I have not located any data connecting temperature to numerical 0 – 10 or 1 – 10 ratings of the painfulness of heat stimuli.

Though the magnitude of the placebo effect with VAS appears small, it is widely reported[8] that perhaps 50% or more of subjects in pain placebo studies do not exhibit the effect at all. Since studies always report group data, the real but rare effects may be double or triple those estimated from group data. This field needs some psychophysical investigations with individual subjects.

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# Perceptual learning in patients with macular degeneration

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Age-related macular degeneration or hereditary retinal dystrophies lead to a loss of central vision. Patients often use a new eccentric fixation area on intact peripheral retina (“preferred retinal locus” PRL) that functions as a pseudo-fovea. We trained this locus in patients with central scotomata and an age-matched control group using a perceptual learning paradigm. We also explored the neural correlates of training using functional magnetic resonance imaging (fMRI). We have obtained and analysed the data of 13 patients (8 males, 5 females; mean age = 63.8 years) and 12 age-matched, normally sighted controls (4 males, 7 females; mean age = 62.1 years). The participants underwent fMRI before training, after 3 training sessions and after a total of 6 training sessions. For training a modified version of a texture discrimination task[1] was used. Participants had to discriminate the global orientation (horizontal/vertical) of three tilted lines, located in their PRL, against a uniform background of horizontal lines. On each trial, the target stimulus was shown for 13 ms, followed by a blank screen with variable stimulus onset asynchrony (SOA) and a mask stimulus. In each block the SOA was adjusted by using an adaptive procedure (two-down, one-up) to determine the 70.7% correct threshold[2]. In each training session participants completed 20 blocks with adaptive SOA adjustment, thus the SOA development over sessions indicates training success. In a pre-training session the initial SOA threshold was determined by running five experimental blocks. This initial SOA threshold was then used in all fMRI sessions and hit rates were measured. During the fMRI sessions the target stimulus was presented either in the PRL or in the opposite hemifield (OppPRL). The participants viewed all test stimuli monocularly. FMRI data were processed by using the SPM8 package and the Marsbar toolbox for region of interest (ROI) analysis. ROIs were obtained for the PRL and OppPRL area in the visual cortex by directly stimulating those areas with flickering checkerboards and object pictures. Both groups, patients ($p = .006$) and controls ($p = .05$), showed a significant learning effect in the SOA development over the six training sessions. A similar effect could be obtained for the hit rates during fMRI sessions, but only the patient group showed significantly higher hit rates for the trained (PRL) vs. the untrained (OppPRL) location ($p = .014$). In the BOLD signal we could observe an increase over the training period in both groups, which was, however, not specific for the trained location. To assess possible transfer effects, patients performed several subtests of the Freiburg Visual Acuity and Contrast Test[3], resulting in a significant improvement in the Vernier task. The results support the idea that perceptual learning improves the efficient use of the PRL location in patients with central vision loss.

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# The role of duration in global loudness evaluation of rising and falling-intensity sounds

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While many psychoacoustical and physiological data obtained so far can be used to better predict the momentary *short-term loudness* of complex time-varying sounds[1], not much is known about the *global loudness* of time-varying sounds, which corresponds to the overall sensation of loudness over their entire duration: Only very basic empirically derived descriptors such as $N_{max}$ or $N_5$ have been proposed to predict it. However, recent studies have demonstrated that these descriptors failed to accurately estimate the *global loudness* of very simple few-seconds time-varying stimuli, certainly because they do not account for the actual perceptual and cognitive mechanisms implicated[2]. The present work explores these mechanisms in the case of 1-kHz rising and falling-intensity tones of several seconds.

Three psychophysical experiments were conducted using Absolute Magnitude Estimation procedures. In the first two experiments ($N = 30$, $N = 16$), the *global loudness* of tones with 15-dB dynamic ranges lasting between 1 and 16 s was assessed. *Global loudness* estimates were observed to increase for both rising and falling-intensity tones for duration up to 6-8 s. Above this duration, the estimates remained constant for rising-intensity tones whereas they were decreased for falling-intensity tones. Furthermore, significant loudness differences were obtained between the two types of stimuli for all durations. Therefore, apart from these “asymmetries” whose origins are still under debate[2], our results suggest that listeners’ overall evaluations are primarily based on an averaging of the loudness maxima over a fixed size temporal window, combined with a “peak-end rule” that weakens this integration in the case of long falling-intensity sounds. The likelihood of this interpretation was supported by the results of a third experiment ($N = 29$) in which rising and falling-intensity tones of duration between 2 and 12 s, varying at 2.5 dB/s or 5 dB/s, were evaluated. In particular, we found that *global loudness* estimates of ramps with similar direction, maximum level and rate of change were almost identical, supporting the view that a certain loudness integration mechanism, independent of the duration of the sound, is involved. The present results may be related to those from various psychological studies, where similar integration rules were observed for driving overall evaluations of various types of intensity-varying episodes, such as overall painfulness of medical or experimental treatments varying in strength[3].

Finally, a model is proposed to predict the *global loudness* of rising and falling-intensity sounds. Deviations from the model predictions are discussed with respect to specific individual strategies.

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# No evidence for an ISI-induced interference effect on temporal processing of empty intervals

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The present study was designed to directly test the notion put forward a while ago[1] that confusion in temporal processing of two successively presented empty intervals is increased if the duration of these intervals is close to that of the interstimulus interval (ISI) separating both these intervals. For this purpose, performance on duration discrimination was assessed for base durations ranging from 400 to 1400 msec presented with an ISI of 900 msec. Four groups of 24 participants each took part in this study. To control for a potential effect of psychophysical task, two different psychophysical tasks were employed: two groups performed a reminder task and two groups a 2AFC task. One group of each task was presented with auditory empty intervals, whereas the other group on each task was presented with visual empty intervals. The weighted up-down method was used to estimate the difference limen (DL) as an indicator of discrimination performance for each base duration. For enhancing the presentation of results, Weber fractions (DL/base duration) were computed and analysed instead of absolute DL values.

For statistical analysis, two-way analyses of variance were performed for auditory and visual empty intervals, respectively, with Task (2AFC and reminder task) as a grouping factor and Base Duration (400, 600, 800, 1000, 1200, and 1400 msec) as a repeated-measurement factor. Performance on duration discrimination was significantly better with the reminder than with the 2 AFC task. This held for both auditory, $F_{(1,46)} = 9.56, p < .01$, and visual empty intervals, $F_{(1,46)} = 16.19, p < .001$. In the case of auditory empty intervals, neither a significant main effect of Base Duration, $F_{(5,230)} = 0.996, p = .42$, nor a significant interaction between Base Duration and Task, $F_{(5,230)} = 1.000, p = .42$, could be observed. For visual empty intervals, two-way analysis of variance yielded a statistically significant main effect of Base Duration, $F_{(5,230)} = 6.864, p < .001$, while the interaction between Base Duration and Task again did not reach the 5%-level of statistical significance, $F_{(5,230)} = 0.998, p = .41$.

Post hoc Scheffé tests revealed that the statistically significant main effect of Base Duration originated from a considerably larger Weber fraction for the shortest (400-msec) base duration compared to the Weber fractions of all the other base durations. Most important, however, there was no indication for an interfering effect on discrimination performance caused by the 900-msec ISI. This held for both auditory and visual empty intervals irrespective of psychophysical task. According to the interference hypothesis[1], with a 900-msec ISI, performance on duration discrimination should had been adversely affected for the 800- and 1000-msec base durations that were much closer to the 900-msec ISI than the remainder of the base durations. Thus, the present findings clearly argue against the idea of an ISI-induced interference effect on temporal processing of empty intervals.

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# Cross-modal measures – the literary evidence

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The popular understanding of psychophysics can be found in literary examples that give comparisons between different sense modalities. Sometimes the quotations are more than similes, because one sensation is scaled against another. Sometimes the comparisons are between individual observers. Borg[1] gave many examples from the Bible and Shakespeare, and recommended his range model to deal with the problem of interindividual comparisons. In this model the strongest perceived intensity for each individual is set subjectively equal for all observers, and is used as a fixed point; the intensity of a sensation is then evaluated according to its relative position in each individual's range from minimum to maximum. An example in a modern story is: "When she [the weak girl] was asked to carry anything, the load felt twice as heavy to her as it did to her stronger sister."[2] However, some proverbs stress the impossibility of interindividual comparison: "None knows the weight of another's burden."[3]

Many examples concern weight and the sensation of heaviness[4]. Weighing scales are a symbol of justice, and can be used to weigh souls or weigh good and bad deeds: hence the English proverb "Good weight and measure is heaven's treasure", and the menacing Biblical writing on the wall "Thou art weighed in the balances and art found wanting" (*Daniel, 5:27*). Heaviness is often used as a metaphor for other sensations and emotions, particularly grief, perhaps because of the physiological effects of grief and depression. In the folk song *The Devil's Nine Questions* there are the lines:

"What is heavier than the lead / And what is better than the bread?
Grief is heavier than the lead / God's blessing's better than the bread."

Heaviness is used in the Koran as an impediment to hearing: "And We have placed coverings on their hearts and a heaviness in their ears lest they understand it, and when you mention your Lord alone in the Quran they turn their backs in aversion" (*The Children of Israel* 17.46)

Bad events may be described as sour or bitter. Shakespeare (*Poems*, xciv) wrote: "For sweetest things turn sourest by their deeds; /Lilies that fester smell far worse than weeds".

Emotions and desires are sometimes quantified in monetary terms, as in modern economic studies into the value of certain places and activities. Shakespeare wrote: "I had rather than forty shillings I had my Book of Songs and Sonnets here" (*The Merry Wives of Windsor*, 1, I, 205). Thus psychophysical scaling is not just an abstruse laboratory activity, but is also practised to some extent by the general public.

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# Adaptation-level theory in retrospect: a modern evaluation

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More than 75 years after Harry Helson (1898–1977) started his work on the relational psychophysics in sensory perception[1], and half a century after the publication of his book "Adaptation-Level Theory"[2], it is time to take stock and evaluate this unique model of perceptual psychology[3]. Thus the main question is if Helson's *AL* theory withstood the test of time. Specifically, why is it that *AL* theory is no longer dealt with as an important concept in current psychophysics research[4,5]?

*AL* theory, originally suggested as a sensory-perceptual construct, has been expanded by Helson and his proponents to whole perception, cognition, and even social psychophysics. Thereby, the adaptation-level is conceived as a so-called neutral stimulus which elicits a "zero" response; and it functions as the "point-of-reference" for all the contextual (surrounding) stimuli of a given psychophysical situation. In the mathematical *AL* model this "reference" point is a monotonic function of (1) the focal stimuli to be judged or behaviorally reacted to, (2) the unjudged anchor ("background") stimuli as contextual inputs, and (3) the remaining so-called residual stimuli (e.g., stimulus "experiences"). Over the years, the *AL* model has been experimentally tested and discussed many times, however – at best – with mixed results; above all, its psychological significance, or validity, has been questioned by quite a few experimental psychologists, for example already by Stanley S. Stevens and his followers[6]. In the present paper, some of the attempted remedies (modifications) of *AL* theory are also presented in the light of their empirical evidence.

In sum, it is concluded that *AL* theory has still a few notable merits, as exemplified in selected subfields of social or applied context psychophysics; however, it still suffers from several experimental and conceptual shortcomings some of which have – indirectly – opened new research avenues in today's psychophysics. In future work, improved versions of *AL* theory may pave the way for the development and testing of some refined models of psychophysics including the case of animal perception and cognition[7].

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# Effects of the distribution of durations of leading tones on the perceived duration of following tones

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When a puretone which has shorter duration than 1000 ms leads another puretone of 1000 ms duration, the *point of subjective equality* (PSE) for the latter extends longer than 1000 ms[1]. In the context of Adaptation-Level theory, this phenomenon can be considered as a kind of anchoring effect; the PSE for the 1000 ms duration puretone represents the Adaptation-Level (AL) of the perceived tonal length. This experiment was conducted under conditions of presenting only one leading tone. If an anchoring effect is prevalent in perception of tonal length, the AL would be determined not only by a single anchoring stimulus but also by the distribution of stimulus values of all the anchors employed in the experimental session. To examine this issue, in the present study, the AL of perceived tonal length was measured as a function of the distribution of durations of the leading tones.

Three male graduates and 1 female graduate participated in the experiment. The frequency and the intensity of tones were set to 1000 Hz and 60 dB respectively. Ramped onset and offset times of 50 ms at the start and end of each tone ensured there were no click noises generated by the rapid onset and offset of the tones. Three conditions were made for the distribution of durations of leading tones, setting upper and lower limits to 250 ms and 750 ms respectively. In this respect, Condition 1 contained more anchors of shorter durations (250, 333, 417, 500, 750 ms); Condition 2 had a linear distribution of durations (250, 375, 500, 625, 750 ms); Condition 3 comprised more anchors of longer durations (250, 500, 583, 667, 750 ms). All the conditions contained the leading 500 ms duration. ALs were psychophysically measured using the method of constant stimuli. Three puretones were presented and participants were requested to judge the length of the third tone, with the leading tone as the anchor, and the second tone as the standard.

Data analysis revealed the following results. In general, the AL of perceived tonal length exhibited larger values when the leading tone was shorter than the standard tone in duration, and smaller values when the leading tone was longer than the standard. ALs obtained with a 500 ms leading tone, which was present in all three conditions, differed from each other depending on the distribution of leading tones.

In sum, the shift of AL can be described as an anchoring effect being dependent on the distribution of leading durations. Furthermore, the PSEs of tonal length, which had the same duration as the leading tone, were found to differ depending on the experimental condition. These results suggest that the perceived length of tones is dependent, not only on the duration of anchoring stimuli presented in each comparative judgment, but also on the distribution of anchors used in the experimental session.

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# The Psychophysical Power Law: Dead or alive

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It is a little over 60 years since Stevens's power law was first proposed and for a period of time it received wide recognition among students of psychophysics. But there were critics as well, and over the years those objections have reached a level where there are now many who feel that it should be repealed, and indeed, that we should abandon the quest for a general principle relating stimulus intensity and perceived magnitude. Some of our colleagues have gathered evidence showing a sharp decline in references to it and the methods used to support it. A Google search for "psychophysical power law" shows a sharp rise in frequency of occurrence, reaching a peak in 1975, then falling to a value barely $1/10$ of that peak. It seems time to assess the existing evidence and make a judgment about the validity of the power law.

Two years ago I did just that, and reported my findings in a publication that has a long record of reports in the field of psychophysics and where much of the early work on the power law appeared (Teghtsoonian, R. (2012), The Standard Model for Perceived Magnitude: A Framework for (Almost) Everything Known About It, *American Journal of Psychology*, 125, 165–174) . My conclusion was that first, there is such a large body of evidence for the law that it seems foolhardy to dismiss it. As far as I know there has been no systematic review of that body of evidence showing it to be fatally flawed. And second, I argued that the power law is one part of a broader framework that accounts for a large part of what may be regarded as the database for the field of psychophysics. Here are its main features:

1) Cross-Modal Matches (CMM) for any pair of perceptual continua (PCs) follow a linear function on logarithmic coordinates, i.e., the matching relation follows a power law. 2) Every prothetic PC is characterized by a distinctive dynamic range (DR), the ratio of the largest intensity that can be experienced to the lowest that can be detected. This measure varies widely among the several PCs. 3) It is hypothesized that the full DR for any given prothetic PC can be exhaustively mapped into the full DR of any other prothetic PC. 4) Items 1, 2, and 3 imply that the slope of the matching function is determined by the relative sizes of the relevant PCs. If a particular PC (e.g., number) is used as the response variable (as in magnitude estimation) for a variety of PCs, the exponents of the various PCs will be inversely related to the DR of each PC. Thus, power law exponents may be seen as indexes of DR. 5) Item 3 implies that the subjective dynamic range (SDR) is a constant for all PCs. 6) Item 5 implies that there exists a single neural mechanism where input from every PC is registered, and that it too has a characteristic DR. It will be interesting to see if neuroscientists are able to locate such a mechanism. 7) Given Item 1, the ratio of two stimuli that are just discriminably different will correspond to a similar ratio on a matching PC, and the relative sizes of these ratios will be defined by the exponent of the power function relating those two PCs.

Evidence supporting these seven ideas has been reported in a series of publications, most of them included in the reference cited above. Taken together they provide a simple model that integrates most of what is known about perceived magnitude. All models, including this one, are bound to be flawed. But I think the challenge is not simply to look for exceptions and what look like negative cases, but to try to create a better model. My hope is that someone reading this will do exactly that.

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# The priming effects of structural information on pitch interval judgements

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In music, inverse and retrograde transformations of melody have long been used as a popular compositional device (e.g. serialism). When explicitly instructed listeners can recognise such transformations of short melodies[1] and evidence suggests they are processed implicitly[2]. The ability to perceive relations between transformations of melodic structure draws comparison with perceptual features of object recognition in the visual domain[3]. The present experiment sought to examine more closely the cognitive processes involved in the perception of transformed melodic structure.

A priming experiment was conducted in which 21 participants judged the direction of pitch intervals at the end of a target melody. This was preceded by a prime melody that was either structurally related to the target (transposed, inverse, retrograde) or unrelated. Stimuli were isochronous 6-note melodies composed from a 5-tone equal temperament scale. Targets were presented after an inter-stimulus interval (ISI) of 500, 2000 or 4000 ms. Adopting a neural model of music perception[4], it was reasoned that any differences in processing for types of structural transformation would be revealed by an interaction between transformation and ISI effects on response times (RT).

RT for related targets was significantly faster than for unrelated targets, $t_{(20)} = 3.72, p < .001$. A 3 x 3 ANOVA on related trials found no effect of target type, but a significant interaction with ISI, $F_{(4,80)} = 3.44, p = .012$. Pairwise comparisons (Bonferroni corrected) revealed faster RT for transposed targets compared with inverse at 500 ms ISI, $p = .047$. At 4000 ms ISI the mean difference between transposed and retrograde targets approached significance, with faster RT for retrograde targets, $p = .065$. This appeared to be due to RT for transposed targets being slower at 4000 ms compared with 500 ms ISI, $p < .001$.

The results support previous findings and suggest transformed melodic structures are processed automatically. As the time between presentation of melody pairs increased, the facilitation effect for transposed melody diminished, indicating memory decay for untransformed structural information. The facilitation effect for transformed melodies remained unaffected over time. It is proposed that this implicates a higher level of structural processing for the recognition of transformed melody.

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# The impact of sleep deprivation on perception of pain

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Sleep is one of the most important states of the human being; it varies significantly both in its structure and in its functions with age. In the neonatal period, sleep has a connection with the maturation of the central nervous system, memory consolidation and learning, maintaining energy, increased protein synthesis and secretion of growth hormone[1].

The interdependent relationship between sleep and pain was initially drawn by Lewin and Dahl[2] who found that pain, not only, interferes with the quantity and quality of sleep, but that insufficient sleep also causes sequels throughout the day that sensitize the child to experience pain and other somatic symptoms. Both adult and pediatric intensive care units impair sleep and the circadian rhythm is markedly diminished or lost. Approximately 20% of awakenings are related to noise and 10% to nursing interventions or medicine, which can lead to sleep deprivation[3].

Changes in sleep quality and painful experiences are both suspected to contribute to poor neurodevelopmental outcomes, especially in newborns with very low birth weight. However, few studies have explored the interrelationship between the two conditions. Studies with animal models, in particular research on neurogenesis in adult rats, have shown that rats deprived of sleep have around 6-8% reduction in the number of new neurons being produced explaining how sleep deprivation has profound effect on synaptic plasticity and cognitive performance. Implications include reduced exploratory behavior and learning difficulties, attention problems, anxiety, shrinkage of the brain, developmental disorders and memory function of the posterior hippocampus and decreased brain plasticity[4]. Evidence from these studies supports the hypothesis that sleep deprivation, especially REM sleep, is associated with compromising processes of the proliferation of granule cells of the adult hippocampus of rats[4].

Continued exposure to pain, such as tracheal intubation, change the sleep wake cycle and can also cause suppression or deprivation of sleep and the effects on subsequent development can be anatomical, behavioral, and of biochemical nature[5]. The aim, here, is to present the state of the art in the scientific literature on sleep deprivation associated with painful experiences in early child development and the role of sleep in the intensive care environment. The intrinsic question is how pain management can enhance sleep wake cycle changes, and perception of pain. We have found evidence that neonatal care programs can influence sleep development and reduce the negative impact of painful events. This evidence is discussed in the perspective of how carefully planned hospital intervention can improve the quality of life and development of premature infants.

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# A diagnostic of the size-weight illusion by lines of subjective equality

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The *size–weight illusion* refers to the phenomenon by which two objects of equal weight may not appear equally heavy if they are of different size, the smaller of the two usually appears to be heavier. What makes the illusion a surprising fact is that heaviness depends on size, in a negative way. A simple descriptive psychophysical model of the illusion is based on the linear equation[1]

$$H = \beta_S \times S + \beta_W \times W, \tag{1}$$

where term $H$ stands for the apparent heaviness of an object; $S$ and $W$ are measures of the physical size and weight of the object; $\beta_S$ and $\beta_W$ are the parameters of the model specifying the relative contribution of $S$ and $W$ in determining $H$. Terms $S$ and $W$ are physical variables, and may be represented on the main axes of a plane, which is the stimulus space of our study; any object having definite size $s$ and weight $w$ may be represented as the point of coordinates $(s, w)$ on that plane.

In our study we used a variant of the psychophysical method of "constant stimuli," setting the participant a three-choice discrimination task where s/he had to judge whether a test stimulus was lighter, heavier, or equally heavy compared with a standard stimulus. The stimuli were three sets of cylinders of equal diameter varying in height and weight. Each stimulus set was composed of 20 cylinders (19 test stimuli + 1 standard stimulus), and differed slightly from the other stimulus sets in terms of the size and weight characterizing the cylinders. For each stimulus set, the participant compared the test-standard couples using the consecutive method (two cylinders were weighed by the same preferred hand in two consecutive moments).

We hypothesized a trinomial logistic response model for estimating (by maximum likelihood) the parameters of *lines of subjective equality (LSE)*, which can be conceived as two-dimensional extensions of the basic psychophysical concept of point of subjective equality *(PSE)*. The estimates thus obtained were relevant to model (1), as they specified the relative contribution of size and weight to apparent heaviness as well as order errors. We found that the estimated parameters of model (1) were significantly *different* in the three stimulus sets. This implies that there cannot be a unique value of $(\beta_S, \beta_W)$ such that model (1) fits the data over the whole stimulus region considered, and therefore this simple model is implausible when referred to the population of objects on which the size-weight illusion may be illustrated.

We also compared the *LSE* obtained when the stimuli were judged by the consecutive method with those obtained when the stimuli were judged by the *simultaneous* method (two cylinders were weighed separately by two hands at the same time). We found that the magnitude of the illusion did not change with the method of comparison, and interpreted this result as evidence of the low-level perceptual nature of the phenomenon[2].

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# Universality versus individuality: Place for inter-individual differences?

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In science we aim at representation of a phenomenal field in a symbolic (usually: mathematical) form. Ideally, the manifold of phenomena under study is represented by a limited number of functional relations, or "laws." These laws should be universally valid and testable (at least in principle) by observation or experiment. We assume that nature "acts" uniformly in all observational situations; however, *uniformity is not the same as identity*. In fact, the universal character of physical laws is essentially due to separation of the general *form* of the laws from circumstances and contingencies of particular observational situations.[1] What does it mean?

Firstly, most laws of physics specify manifolds of observable world-states in theoretical terms; they do not predict observational data directly. Experiment is to be understood as an empirical instantiation of the physical theory; consequently, the mediation between experimental data and the underlying theory is itself a particular task for the theory—another "layer" of the theoretical background, so to speak. Secondly, and no less importantly: looking at mathematical expressions of empirical laws in physics, we find indeterminate parameters assumed to be constant for a particular observational situation, but possibly varying between different situations. These parameters may refer to specific properties of physical objects—such as specific density, heat capacity, electrical resistance, etc., for short: "material constants"— or to singular experimental conditions, properties of the measurement apparatus, etc., for short: "instrumental constants." Occurrence of such "adjustable constants" in laws of physics is not a defect or limitation of their applicability but rather *manifestation* of their universality.

The lesson to be taken from elementary physics for psychophysics: uniformity of nature does not require nor imply identity of effects across individuals. Consequently, inter-individual differences should be taken into account in mathematical modeling of experimental data, and not just circumvented by conveniently thoughtless reduction to group averages. Adequate functional representation of experimental effects may, and usually will, require additional degrees of freedom provided by properly placed "adjustable constants."

These theoretical considerations shall be illustrated by our experimental data on the Oppel–Kundt phenomenon[2], one of the classic "geometric–optical illusions." There the effect magnitude (relative expansion of a linear extent in the visual field) occurs to be a non-linear and non-monotonic function of the stimulus (number of visual elements subdividing the perceived extent). We will describe a phenomenological model[3] of this dependence, using a prototype function with two adjustable parameters representing individual "susceptibility" for and "expressivity" of the illusory effect. We will eventually show how results obtained with the adjustable parameters strategy differ from a simple functional fit to group-averaged data.

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# The lightness of Ebbinghaus like figures with illusory contours

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Our purpose was to modify the enhanced lightness, at the basis of the appearance of 'anomalous' figures[1], by the illusory modification of their size, which previous experiments have proved to affect perceived lightness[2]. We hypothesize that the packs contributing to the onset of an anomalous disk can behave as inducers in an Ebbinghaus like display[3]: the smaller the packs, the larger the 'opaque' figure.

Three disks were created (Photoshop Grayscale) by black packs of increasing size on a light grey background (b92/rgb236). As the packs were enlarged their number was reduced to counteract the increased contrast effect. Two conventional disks of the same geometrical size (8 cm diameter), one (A) darker (b89/rgb226) and one (B) lighter (b95/rgb242) than the background, were added. The displays were presented on a monitor (3 sec, randomly at intervals) according to *Pair Comparison Method*[4]. Thirty observers (aged 20-25) were asked (twice) first "which disk looks larger", then "which disk looks lighter" in each pair.

Fig. n. 1 Experimental displays

Scale separations have been computed. The magnitude and the lightness of the anomalous disks are affected by the size of the packs; nonetheless the order and the distance of the stimuli on the two continua differ. All the anomalous figures appear larger than those without any inducer. Disk D looks the largest (E < C < D). Disk E (the smallest except A and B) looks the lightest excluding B; disk D (the largest), looks the darkest (D < C < E) excluding A. Observed proportions do not differ from expected ones (magnitude: $\chi^2{}_{(6,\,N=30)} = 9.07, p < .20 > .10$; lightness: $\chi^2{}_{(6,\,N=30)} = 10.68, p > .10$). As each display exhibits the same contrast level we can suppose that the modifications in lightness are connected to figural factors, the same that affect the perceived size. We can hypothesize a sort of *equilibrium* between the lightening due to the illusory enlargement[3] and the "drop of energy"[5] ensuing from the appearing of a larger anomalous figure.

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# IAMFaRR: Maximum range of face recognition

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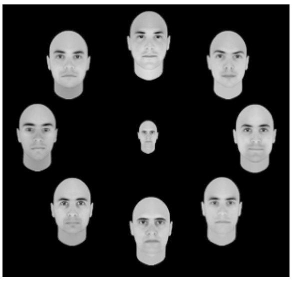
Individuals with visual impairments are often assessed using high-contrast letter acuity charts (ETDRS, Landolt-C). However, those who experience difficulty recognizing faces may not be accurately assessed by these methods due to the fundamentally different nature of face and letter recognition. Difficulty recognizing faces can affect one's ability to perform basic daily tasks, and yet there is currently no validated clinical tool to measure face recognition[1]. To fill this void, the Individual Assessment of Maximum Face Recognition Range (IAMFaRR) was developed, a test which estimates the maximum distance at which one can recognize a face.



Twenty undergraduate students from the University of Ottawa, ages 17-24, participated in Experiment 1. Visual acuities ranged from 20/10 to 20/30. For Experiment 2, 17 undergraduate and community participants, ages 18-30, were recruited. Visual acuities ranged from 20/10 to 20/100. For Experiment 1, 8 faces were selected from Matheson and McMullen's face database based on pilot data. The task was an 8AFC match-to-sample task wherein the target face was presented in the middle of the screen surrounded by potential match faces. Viewing distance was 195 cm. An interleaved staircase method with 5 staircases each having 80 trials was employed to find the smallest face stimulus a participant could reliably match to the surrounding sample faces. Stimulus size began at 8.3 cm. Experiment 2 used the same procedure and stimuli, however participants were provided with the array of potential match faces on a computer screen at a distance of 57 cm and the target face was presented on a second screen at a distance of 195 cm. For Experiments 1 and 2, participants first completed the Freiburg Visual Acuity and Contrast Test (FrACT) to assess letter acuity.

Threshold results of the IAMFaRR for Experiment 1 were compared with the results from the FrACT. Results demonstrated a strong correlation and linear relationship between letter acuity and results on the AMFaRR task ($r^2 = .42$). For Experiment 2, threshold results of the IAMFaRR were compared with the FrACT, showing a non-linear relationship between the two ($r^2 = .85$).

Face recognition requires middle relative spatial frequency information[2]. When acuity is poor, perceiving mid-range spatial frequency information becomes impaired, and the maximum distance of recognition decreases. Hence, a non-linear relationship between the IAMFaRR results and visual acuity is expected. Experiment 1 tested a restricted range of visual acuities (20/10 to 20/30) and found a linear relationship between the variables. In contrast, Experiment 2 tested participants of a wider age range and visual acuities (20/10 to 20/100), and an altered set-up allowed participants to better see the references faces. Results from the second study demonstrated a non-linear relationship between letter and face recognition, in accordance with our previous work. Further research is required to test a wider range of acuities and those with visual disorders.

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