It turned out that the gap transfer illusion takes place even when the short glide is down to 8 dB below the level of the long glide. This supports our claim that the illusory continuity of the long glide in the gap transfer illusion is different from the continuity illusion in its typical form. It is required for the occurrence of the continuity illusion that the inserted tone be intense enough to be a potential masker of the discontinuous tone (Warren et al., 1999). It is difficult to assume that the long glide can be masked with the short glide less intense than the long glide.

Our results may imply a high ability of auditory completion. The gap transfer illusion took place when a discontinuous long glide crossed with a less intense continuous short glide, but there should be a lack of sound energy, up to 8 dB, to fill in the gap of the long glide even if the sound energy of the short glide is allocated to the long glide. We should perceive discontinuity for the temporal dip, but the gap transfer illusion took place in such a stimulus condition, and the long glide was perceived as continuous. Auditory system behaves as if it could generate new energy to fill in the gap.

Acknowledgment

The research was supported by the Japan Society for the Promotion of Science (19103003 in the fiscal years 2007-2011; 20330152 in the fiscal years 2008-2012).

References

Nakajima, Y., Sasaki, T., Kanafuka, K., Miyamoto, A., Remijn, G., & ten Hoopen, G. (2000). Illusory recouplings of onsets and terminations of glide tone components. *Perception & Psychophysics*, *62*, 1413-1425.

Warren, R. M. (1999). *Auditory perception: A new analysis and synthesis*. Cambridge: Cambridge University Press.

Warren, R. M., Obusek, C. J., & Ackroff, J. M. (1972). Auditory induction: perceptual synthesis of absent sounds. *Science*, *176*, 1149-1151.

DIFFERENCES BETWEEN "EARLY" AND "LATE" PROCESSING OF STIMULUS DIMENSIONS IN PERCEPTION? THE ROLE OF CONTEXT INVARIANCE

Daniel Algom
Department of Psychology, Tel-Aviv University, algomd@freud.tau.ac.il

Abstract

When a pair of dimensions is tested for perceptual interaction, the outcome can depend on the task at hand. In particular, inconsistencies are found when the same dimensions are tested in detection and in 'higher-level' judgments. The so-called Redundant Signals Design in detection and Functional Measurement in judgment are discussed for illustration. It is shown that the notion of context invariance is critical for a theoretical resolution.

Rectangles have been a popular tool to assess perceptual interaction with height and width as natural input dimensions. Their components, pairs of vertical and horizontal line segments approximating an L-shape, have similarly been used to probe separability or independence in perception. In fact, the vertical and horizontal position of a single dot placed within a rectangle (Garner & Felfoldy, 1970) can also serve to address the presence and nature of the interaction between the two dimensions. The gamut of tasks used varied from detection (Kadouri-Labin, 2008; Townsend, Hu, & Ashby, 1981) to identification (Monahan & Lockhead, 1977; Weintraub, 1971) to speeded classification (MacMillan & Ornstein, 1998) to judgments of similarity (Schonemann, Dorcey, & Kienapple, 1985) to judgments of area (Algom, Wolf, & Bergman, 1985; Anderson & Cuneo, 1978; Wilkening & Lange, 1989). Notably, the results varied across tasks (and, to a much lesser extent, within tasks), sometimes in a qualitative way. Detection and estimation of area can provide one illustration. For detection, horizontal and vertical line segments were often found to interact, whereas height and width were often found additive in judgments of the area of the respective rectangles (with children). The inconsistency is typical of many other dimensions. My goal in this article is to pinpoint one possible source for the inconsistency. I refer to a critical assumption that has been recognized in detection, but that has not been fully recognized in the more "cognitive" tasks of integration such as estimation of area. The assumption is known as context invariance (Townsend & Wenger, 2005) or context independence (Colonius, 1990).

Detection and Context Invariance

In a simple detection design, the Redundant Targets Paradigm (RTP), a horizontal line (signal A), a vertical line (signal B), both (A&B), or none is presented on a trial and the observer indicates the presence of any signal as fast as possible (espousing a minimum time stopping rule). It has often been observed that reaction times are stochastically faster on the redundant signals (A&B) trials than on the single signal (A, B) trials, the Redundant Targets Effect (RTE). The RTE, in turn, figures prominently in attempts to characterize the architecture of the system processing the signals. The assumption of context invariance is critical for the success of these attempts: We assume that the rate of processing along the vertical (horizontal) line channel is invariant across single- and redundant-targets presentations. In other words, we assume that the vertical line is processed in the same way regardless of whether the horizontal line is also presented on that trial; the same holds for the processing of the horizontal line. Only with this assumption in force is one justified in making the key comparison between single- and redundant-targets trials.

The crucial importance of context invariance is evident when one makes use of a major regularity pointed out by Miller (1982). If the processing of A&B is accomplished within a separate race architecture with the winner of the race determining the response on each trial then the probability distribution function should be less than or equal to the sum of the single target probability distribution functions. Stated in equation form,
$P_{AB}(T_{AB} \le t) \le P_A(T_A \le t) + P_B(T_B \le t)$, where the subscripts depict the signal(s) presented. The inequality holds for any race model. Conversely, violation of the inequality falsifies all race models. Consequently, the inequality has been widely used to test for interactions between posited perceptual processes (Townsend & Honey, 2007). Miller himself concluded that, since his data violated the inequality, information is combined before a decision is made.

It was later noticed that Miller's prediction depends on the critical assumption of context invariance, namely $P_A(T_A \le t) = P_{AB}(T_A \le t)$ and $P_B(T_B \le t) = P_{AB}(T_B \le t)$, where the right-hand term in each equation is the marginal cdf for processing that target in the context of the other being present. As Luce (1986, p. 131) notes, "it is difficult to know how to verify" the assumption of context invariance. My main point in this brief discussion is to highlight the fact that the importance of context invariance has been recognized (if not yet tested) within detection research with several ramifications worked out (Colonius, 1990; Townsend & Wegner, 2005). The situation is different with methods tapping "higher level" cognitive processes such as the integration of height and width in judgments of the area of rectangles. Portions of that research have been carried out within the framework of Functional Measurement (Anderson, 1981, 1982).

Functional Measurement and Context Invariance

In studies of Functional Measurement, the task for the observer is to estimate a variable, C (say area), other than either A (height) or B (width). Hence the need to integrate. Model analysis focuses on the way that the *psychological* values of A and B are integrated to produce C. The processing model for a given stimulus, A_iB_j, is well known (Figure 1): A_i and B_j are valuated to obtain the psychological representations a_i and b_j, respectively. These are integrated (c_{ij}) to produce C_{ij}.

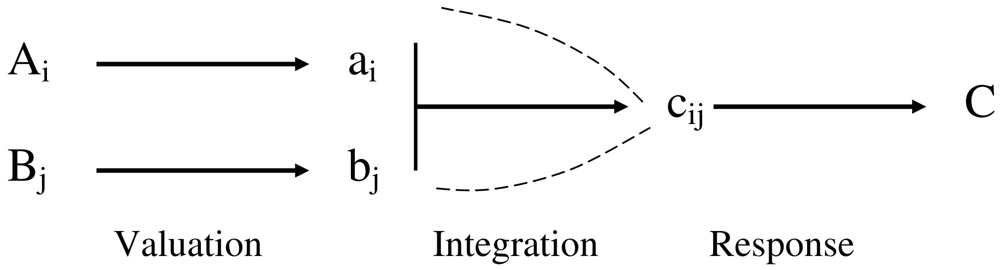

Figure 1: Presented with stimulus A_iB_j, the observer valuates each of the components onto the corresponding psychological values, a_i and b_j. The result of their integration, c_{ij}, produces the observable response, C_{ij}.

Of particular interest might be the adding model, $c_{ij} = a_i + b_j$, because, to a first approximation, it implies the separability of A and B in processing. Once the unobservable values are tied together with the observable ones through (at least) monotone functions, the separability of A and B with respect top C may become observable through the parallelism in the factorial plot (Figure 2).

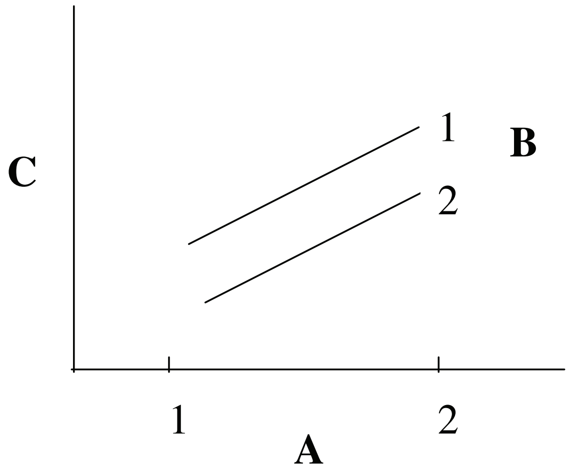

Figure 2: Parallelism pattern supports an adding-type rule of integration of A and B with respect to C. Simultaneously, it might support the separability of A and B in perceptual processing.

How does the parallelism observed in Figure 2 speak to the issue of independence or separability of A and B? The answer is not simple because separability is always conjoined with integration within Functional Measurement. Separability or independence of A and B means that the scale value a_i (b_j) of stimulus A_i (B_j) remains constant, regardless of what other stimuli it is combined with (see Anderson, 1981, pp. 18-21). This property is independent of the pertinent integration rule. For example, an adding rule of integration can operate in the *absence* of stimulus independence or separability. In this case, the stimuli interact to change one another's scale values, and then an adding-type model acts on those momentary scale values.

However, the assumption of separability, indeed of context invariance, is vital for the derivation of parallelism. With context invariance in force, the scale value of each stimulus remains constant in the face of various combinations with other stimuli. Acting on such scale values with an adding-type rule of integration must produce parallelism as proved by Anderson (1981, pp. 15-17). Therefore, "the independence assumption is essential for the parallelism test" (Anderson, 1981, p. 19).

Can parallelism or its absence serve as a test of separability or independence? Anderson (1981, p. 19) argues that it can: "observed parallelism supports the independence assumption." This might well be the case in practice, but the argument is not infallible. When the scale values of the stimuli vary due to interaction (i.e., due to the lack of independence), adding them would not generally result in parallelism. In this sense, the lack of parallelism does support violation of independence. However, the changing scale values might fortuitously cancel in a way that produces parallelism upon adding. Although the chances are slight for such an eventuality, it cannot be ruled out.

The independence of integration and separability applies with other rules of integration within Functional Measurement. Consider the multiplying model, which yields a radiating fan of straight lines on visual inspection. Proof of the linear fan theorem (Anderson, 1981, p. 41-42) is also based on the independence assumption, namely, on the assumption that the scale values of the stimuli remain constant in the face of the factorial combinations. Only with constant stimulus values does a multiplication rule result in the linear fan property. However, a multiplication rule can operate on stimulus scale values that vary from combination-to-combination due to the failure of independence. In this case, the set of straight lines would not in general follow.

Espousing the logic used with respect to parallelism, Anderson (1981, p. 43) argues that, “an observed linear fan pattern supports the independence assumption.” However, observing a linear fan may provide a weaker test than does observed parallelism. Various combinations of changing scale values (i.e., violating independence) can produce approximations to a linear fan.

More Empirical Evidence

Consider pain studied via detection and via integration. Employing the methods of General Recognition Theory (Ashby & Townsend, 1986), Algom & Edelstein (1998) used 2 levels of electrical current applied to the underside of the wrist and 2 levels of uncomfortably loud noise fed to the ears. These painful stimuli were combined in a factorial design and the combinations were presented, one at a time, to the observer. We used the reports of the observers to calculate values of d’ for shock twice: once with noise at a constant less intense level, and once with noise at a constant more intense level. The d’ values for the same shocks differed at the two levels of the noise. They were 1.627 and 1.217, respectively, with noise at milder and louder levels. We similarly calculated a pair of d’ values for noise with shock at less intense and more intense levels. Again, the d’ values for the same noises did not remain invariant across the two levels of shock. The values were 1.849 and 1.218 for shock held at lower and higher levels. Clearly, shock-induced pain was not perceptually separable from noise-induced pain, and noise-induced pain was not perceptually separable from shock-induced pain. Separability failed for both dimensions.

However, when the observers made magnitude estimates of the overall painfulness of such compound stimuli (Algom, Raphaeli, & Cohen-Raz, 1986), the data were consistent with an adding-type integration: The estimates of pain approximated the linear sum of the pain estimates of the individual electrical and auditory components. The lack of a shock x tone interaction supported the observed parallelism in the factorial plot. Following Anderson (1981), observed parallelism supports the independence of the implicit scale values for the two stimulus dimensions. This conclusion is incompatible with that reached on the basis General Recognition Theory testing. Again, context invariance may be the key to resolve the nonuniformity.

Conclusion

Clearly, context invariance is as crucial an assumption within Functional Measurement as it is within the RTP or other designs probing “early” detection. And, it is as difficult to know how to verify its presence within Functional Measurement as it is in detection. If the assumption is violated then the validity of any observed rule of integration is suspect. The indeterminacy can explain the inconsistency noted in the outset of the article with respect to horizontal and vertical extent as well as with other stimulus dimensions.

References

Algom, D., & Edelstein, A. (1998). Selective attention to pain stimuli. In S. Grondin, & Y. Lacouture (Eds.), *Fechner Day 98’* Quebeck: International Society for Psychophysics.

Algom, D., Raphaeli, N., & Cohen-Raz, L. (1986). Integration of noxious stimulation across separate somatosensory communication systems: A functional theory of pain. *Journal of Experimental Psychology: Human Perception and Performance, 12*, 92-102.

Algom, D., Wolf, Y., & Bergman, B. (1985). Integration of stimulus dimensions in perception and memory: Composition rules and psychophysical relations. *Journal of Experimental Psychology: General, 114,* 451-471.

Anderson, N. H. (1981). *Foundations of information integration theory*. New York: Academic Press.

Anderson, N. H. (1982). *Methods of information integration theory*. New York: Academic Press.

Anderson, N. H., & Cuneo, D. O. (1978). The Height + Width rule in children’s judgments of quantity. *Journal of Experimental Psychology: General, 107*, 335-378.

Ashby, F. G., & Townsend, J. T. (1986). Varieties of perceptual independence. *Psychological Review, 93,* 154-179.

Colonius, H. (1990). Possibly dependent probability summation of reaction time. *Journal of Mathematical Psychology, 34,* 253-275.

Garner, W. R., & Felfoldy, G. L. (1970). Integrality of stimulus dimensions in various types of information processing. *Cognitive Psychology, 1,* 225-241.

Kadouri-Labin, S. (2008). *Is perceptual separability separable?* Unpublished doctoral dissertation. Tel-Aviv University.

Luce, R. D. (1986). *Response times*. New York: Oxford University Press.

MacMillan, N. A., & Ornstein, A. S.(1998). The mean-integral representation of rectangles. *Perception & Psychophysics, 60,* 250-262.

Miller, J. (1982). Divided attention: Evidence for coactivation with redundant signals. *Cognitive Psychology, 14*, 247-279.

Monahan, J. S., & Lochead, G. R. (1977). Identification of integral stimuli. *Journal of Experimental Psychology: General, 106*, 94-110.

Schonemann, P. H., Dorcey, T., & Kienapple, K. (1985). Subadditive concatenation of dissimilarity judgments. *Perception & Psychophysics, 38*, 1-17.

Townesnd, J. T., Hu, G. G., & Ashby, F. G. (1981). Perceptual sampling of orthogonal straight line features. *Psychological Research, 43*, 259-275.

Townsend, J. T., & Honey, C. (2007). Consequences of base time for redundant signals experiments. *Journal of Mathematical Psychology, 51*, 242-265.

Townsend, J. T., & Wenger, M. J. (2004). A theory of interactive parallel processing: New capacity measures and predictions for a response time inequality series. *Psychological Review, 114*, 1003-1035.

Wilkening, F., & Lange, K. (1989). When is children's perception holistic? Goals and styles in processing multidimensional stimuli (pp. 141-171). In T. Globerson & T. Zelniker (Eds.), *Cognitive style and cognitive development*. Norwood, NJ: Ablex

INDIVIDUAL DIFFERENCES IN STARTING POINT LOCALIZATION OF MOVING OBJECTS: DATA ANALYSIS USING MULTILEVEL/HIERARCHICAL MODELS.

Bastianelli A., Actis-Grosso R*., Altoè G., Vidotto G., Stucchi N*.
Department of General Psychology, University of Padua, Italy
*Department of Psychology, University of Milano-Bicocca, Italy
alessia.bastianelli@unipd.it

Abstract

When observers are asked to localize the starting point (SP) of a moving target, the perceived position is reported both in and opposite to the direction of motion. It is still not clear under which conditions the perceived SP is mislocalized back or forth. Although research has shown a remarkable inter-individual variability, only few studies mentioned this aspect, which seems to be crucial to understanding whether the observers used different evaluating systems on judging the SP or it is due to methodological aspects. In the present study, we used multilevel models to choose between these two alternatives analyzing individual variability in localizing SP as a function of both velocity and direction. Results showed an individual variability, suggesting that observers used different evaluating systems when asked to localize the SP of a moving target.

A wide body of research has focused interest on the perceived position of a moving stimulus (e.g. Fröhlich, 1923; Mac Kay, 1958; Freyd & Finke, 1984; Hubbard & Bharucha, 1988; Nijhawan, 1994; Müsseler & Aschersleben, 1988; Thorton, 2002; Actis-Grosso & Stucchi 2003). This interest is based on the observation that there are small but consistent errors, here defined as spatial dislocations, when a position judgement is required for a moving object at both its starting point (SP) and vanishing point (VP) or when a flash is presented aligned with the moving object (Flash-lag effect, FLE). With respect to the SP, the first perceived position of a moving target is typically mislocalized. A localization error in the direction of motion (i.e., a forward mislocation) was firstly reported by Fröhlich (1923), whereas more recent studies also revealed a reverse error, that is an error opposite to the direction of motion (i.e. a backward mislocation; Actis-Grosso, Stucchi & Vicario, 1996). Several explanations have been proposed, however, many questions concerning the nature of these errors remain unanswered.

Regarding the FLE, several studies report individual variability (Baldo & Klein, 1995; Lappe & Krekelberg, 1998; Krekelberg & Lappe, 1999; Patel et al, 2000; Kreegipuu & Allik, 2003). In particular, Baldo and Klein (1995) report that one observer out of five did not perceive any spatial dislocation on FLE, whereas two studies (Lappe & Krekelberg, 1998; Patel et al, 2000) report that some observers showed the opposite effect (i.e. flash-lead). In other research (Lappe & Krekelberg, 1998; Krekelberg & Lappe, 1999) a great variability in the magnitude of the FLE between subjects was present. However, little is known about whether or not different populations exhibit similar levels of individual variability: despite the observation that there is variability between subjects in the perception of the FLE, there are no studies to date that try to analyse whether this difference reflects different strategies in judgment or whether it is due to a different "calibration" of the perceptual mechanism. In fact, it is possible that when an observer is required to judge the position of a moving object, he/she perceives this position with a fixed bias that could differ between subjects. In other words, in principle, it is possible that observers could be divided into three different categories, depending on their precision in the