

The Size Congruity Effect in Visual Search: Further Evidence for Late Interaction

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ABSTRACT. In traditional numerical comparison tasks, participants view 2 digits that have different numerical and physical sizes, and select the digit that is numerically (or physically) smaller (or larger). Responses are typically faster when the numerical and physical sizes are congruent (e.g., the numerically larger item is also physically larger than the other item) than when they are incongruent; this is the size congruity effect (SCE). The SCE reveals that numerical and physical sizes interact, but there is currently disagreement about whether the interaction occurs early or late in mental processing. Recent studies have revealed an SCE in visual search for multiple (i.e., more than 2) search items. In one of these studies, search was slower for participants who were instructed to search for the item with unique numerical size than for participants who were instructed to search for the item with unique physical size. In our experiment, we primed participants in the first block to search for the item with unique physical size. The early interaction model predicts relatively fast search in the second block, but the late interaction model predicts relatively slow search in the second block. Results from the second block were relatively slow, $F(1, 13) = 96.40$, $p < .001$, $\eta_p^2 = .88$, thereby supporting the late interaction model, which is consistent with a growing number of studies that also support the late interaction model.

In numerical comparison tasks (e.g., Besner & Coltheart, 1979), participants view two numerals that have different numerical and physical sizes, and then select the numeral that is numerically (or physically) smaller (or larger). The typical result is a size congruity effect (SCE), wherein responses are faster when the numerical and physical sizes are congruent (e.g., the numerically larger item is also physically larger than the other item) than when they are incongruent (Santens & Verguts, 2011).

Although the SCE shows that mental representations of numerical and physical size must interact, there remains disagreement about where the interaction occurs (Arend & Henik, 2015). In the early interaction model (Reike & Schwarz, 2017; Schwarz & Heinze, 1998), numerical and physical sizes are encoded into a single mental representation, and proceed together through the entire

mental processing sequence. In the late interaction model (Faulkenberry, Cruise, Lavro, & Shaki, 2016; Santens & Verguts, 2011), numerical and physical size inhabit separate mental representations that remain segregated from each other throughout the early stages of processing, and only interact at the decision stage. In this article, we used the SCE in visual search to test predictions made by the early and late interaction models.

The SCE in Visual Search

Risko, Maloney, and Fugelsang (2013) argued that the traditional numerical comparison task is influenced by attention. Because visual search is a widely used method for investigating the role of attention in finding a single target item among several nontarget distractors, Risko et al.'s argument implies that the traditional two-item

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numerical comparison task is simply a visual search with one target and just one distractor. Later work verified that the SCE occurs in visual search with multiple numerals (Krause, Bekkering, Pratt, & Lindemann, 2017; Sobel & Puri, 2018; Sobel, Puri, & Faulkenberry, 2016); participants can find a target numeral more quickly when its numerical and physical sizes are congruent than when they are incongruent. Although the SCE in visual search has been observed in three different studies, the fact that incongruity between a target's numerical and physical size can influence visual search remains surprising. After all, visual search is typically presumed to be guided by visual features such as physical size but not by a character's semantic associations such as numerical size (Wolfe & Horowitz, 2004). The presence of the SCE in visual search can be explained more readily in terms of the late interaction model than the early interaction model.

In visual search, participants first select one item from among several in the visual field, then examine the selected item to decide if it is the target; thus, selection is relatively early in the visual processing sequence, and decision is relatively late. In the early interaction model, numerical and physical size are fused together into a single mental representation throughout the entire visual processing sequence (i.e., both selection and decision). In the late interaction model, numerical and physical size are segregated from each other during the early stages (i.e., selection), then numerical and physical size interact during the decision stage. Thus, according to the late interaction model, but not the early interaction model, because numerical and physical size are segregated from each other during selection, the selection stage can be guided by salient visual features such as physical size without any influence from semantic features such as numerical size. Furthermore, because numerical and physical size interact in the decision stage, incongruity between numerical and physical size has the opportunity to influence the decision stage only after attention has already been directed to a display item. As a result, the late interaction model can explain why the size congruity influences visual search even though numerical size is unlikely to be a guiding feature (i.e., does not affect selection).

Using Priming to Encourage Search for Physical Size

Whereas the late selection model can explain how the SCE can occur in visual search, we wanted to try to understand another surprising result from

Sobel et al. (2016). In every display, the target was numerically and physically unique, which enabled Sobel et al. to use the same visual displays in both experiments while manipulating just the instructions (i.e., find the numerically unique item in one experiment, and find the physically unique item in the other experiment). Sobel et al. found that participants who were instructed to search for a three-digit target numeral based on its numerical size responded more slowly than other participants who were instructed to search for the target based on its physical size. That is, participants instructed to search for the item with unique numerical size failed to realize that they could have responded faster if instead they searched for the item with the unique physical size. We wondered why participants failed to realize that they could have just searched for the physically unique item, thereby responding more quickly.

Perhaps if participants were primed to search for the item with unique physical size, they could then continue to use physical size to locate the target even when instructed to search for the item with unique numerical size. After all, visual priming can encourage participants to attend to locations (Chun & Nakayama, 2000; Olds & Fockler, 2004) and visual features (Sobel, Gerrie, Poole, & Kane, 2007) that enable them to search more quickly than if they had not been primed, even without any explicit instructions to do so. With that in mind, we thought that participants could be primed by instructing them to search for physical size in one experimental block, and then instructing them to search for numerical size in the second block.

We blended two experiments from Sobel et al. (2016) into one, instructing participants to search for the physically unique item in the first block, and for the numerically unique item in the second block. The early and late interaction models make two different predictions. If numerical and physical size are fused into a single mental representation during the selection stage as in the early interaction model, in the second block participants should be able to flexibly deploy attention from one feature (numerical size) to another feature (physical size) in the same mental representation. As a result, participants instructed to attend to numerical size in the second block should be able to deploy their attention to the physically unique item, thereby responding as quickly as they had responded in the first block. On the other hand, if numerical and physical size are segregated from each other in two separate mental representations during the

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selection stage as in the late interaction model, participants should be less able to flexibly deploy their attention between numerical and physical size. As a result, participants should search for the numerically unique item as instructed in the second block, thereby responding more slowly than in the first block.

Hypotheses and Experimental Design

As mentioned previously, it was surprising that participants in Sobel et al. (2016) who were instructed to search for numerical size failed to realize that they could have completed the task much faster if they had searched for the item with unique physical size. Accordingly, we hypothesized that priming participants to search for the physically unique items in the first block would make them realize that they could continue relying on physical size in the second block. Thus, we expected responses to be as fast in the second block as in the first, which would provide support for the early interaction model.

As in Sobel et al. (2016), we chose to elicit a localization judgment (i.e., indicate whether the target is on the right or left side of the display) rather than the better-known detection judgment (i.e., indicate whether the target is present or absent) due to methodological problems associated with detection. For example, in target-present trials, participants use a different decision criterion for terminating search than in target-absent trials (Chun & Wolfe, 1996). As a result, the experimenter must analyze the results from target-present and target-absent trials separately, thereby reducing statistical power. Localization is a widely used method for avoiding the problems associated with detection (Dukewich & Klein, 2009).

Visual search researchers typically manipulate the number of items in the search display because the slope of response times (RT) as a function of the number of display items indicates search efficiency (Wolfe, 1998). In the theoretical extreme, RT that is flat across varying number of display items shows that participants can process all the display items at one time in parallel, whereas steep slopes show that each display item must be processed serially. Physical size but not numerical size is typically presumed to be a guiding feature (Wolfe & Horowitz, 2004), such that a guiding feature is one that enables participants to reduce the range of display items through which search proceeds. Thus, searching for physical size should yield relatively flatter RT functions than searching for

numerical size. Because the early selection model but not the late selection model predicts that the first block should prime participants to search for physical size in the second block, the early selection model predicts that slopes of RT as a function of the number of display items should be as flat in the second block as in the first, whereas the late interaction model predicts that slopes should be steeper in the second block than in the first.

Method

We obtained permission to carry out the experiment from our university's Institutional Review Board. All participants were treated according to the ethical guidelines stipulated by the American Psychological Association (2017). The title of our IRB proposal was *The Interaction Between Perception and Cognition in Visual Search*, proposal number 18-009. To determine the appropriate sample size for the critical experiment, we carried out a pilot experiment to estimate the effect size (ES).

Pilot Experiment

The pilot experiment was intended to find an appropriate sample size to reliably detect an RT difference between attended feature conditions. As mentioned previously, Sobel et al. (2016) manipulated attended feature (i.e., attend to physical size and attend to numerical size) between subjects, whereas in our critical experiment we intended to expose all participants to both levels of attended feature. Thus, when designing the pilot experiment, we wanted to expose all participants to both levels of attended feature as in the critical experiment. However, we hypothesized that instructing participants to attend to physical size in the first block would eliminate RT differences between blocks. Because Sobel et al. (2016) manipulated attended feature between subjects, participants who were instructed to attend to numerical size had not been primed by previously attending to physical size. To replicate the lack of priming when attending to numerical size, we instructed participants in our pilot experiment to attend to numerical size in the first block. Because physical size is a guiding feature in visual search, we expected that the visual salience of physical size should enable participants to localize the target quickly, regardless of whether they had previously attended to numerical size, so in the second block we instructed participants to attend to physical size. Thus, in the pilot experiment, all participants were exposed to both attended feature conditions just as in the critical experiment, but in

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the pilot the block order was reversed to eliminate the priming effect due to attending to physical size.

A total of 16 students (13 female, three male) from a midsized university in the midsouth between the ages of 19 and 57 ($M = 24.00$, $SD = 9.51$) participated in the pilot experiment in exchange for course credit. To calculate ES in the pilot experiment, we divided the mean RT difference between blocks by the standard deviation pooled across blocks (Bausell & Li, 2002). The mean RT when participants were instructed to attend to numerical size was 1016.81 milliseconds, and when they were instructed to attend to physical size the mean RT was 552.68 milliseconds. The pooled standard deviation was 354.80 milliseconds, so the resulting ES was 1.31. To be conservative, we rounded the observed ES from 1.31 down to 1.25, which appears in ES tables for paired t tests in Bausell and Li. Accordingly, an ES of 1.25 in the critical experiment would require a minimum of 9 participants to achieve a power of 80% at an alpha of 0.05.

Participants

A total of 17 students (14 female, three male) from a midsized university in the midsouth between the ages of 18 and 25 ($M = 21.10$, $SD = 1.90$) participated in the critical experiment in exchange for course credit. Students in a wide variety of psychology courses may earn credit for participating in experiments, at the discretion of the professor. To participate, students are directed to an online scheduling system. Every student who made an

appointment on the online system was selected to participate in the experiment. Researchers who carry out visual search experiments do not customarily gather any information about their participants' race and ethnicity, primarily because these factors are not typically presumed to systematically influence basic visual processing. To be consistent with the visual search literature, we did not record our participants' racial or ethnic background.

Apparatus

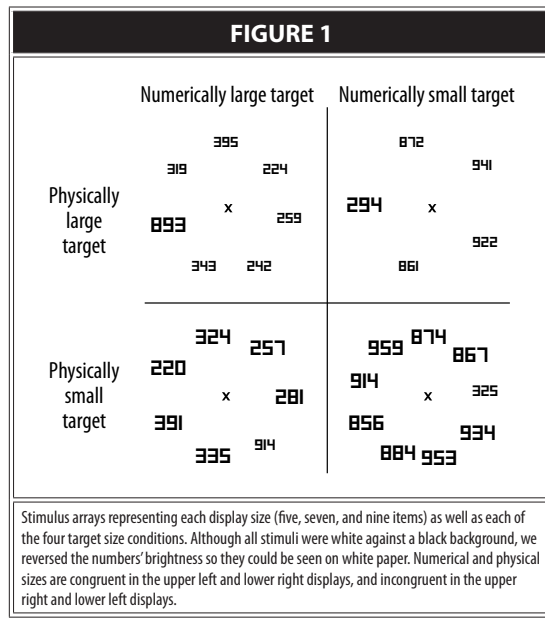
A custom-written visual search program written in Xojo basic running on a MacBook laptop presented the visual search stimuli and gathered the RTs.

Stimuli

Each search display contained a three-digit target number and 4, 6, or 8 three-digit distractor numbers. All the search items were arranged on an imaginary circle with a center marked with an X. For each search item, the hundreds digit was a 2 or 3 (numerically small) or 8 or 9 (numerically large). The tens and units digits were randomly selected from the digits between 0 and 9. At a viewing distance of 60 cm, the physically small numerals were 0.61° wide × 1.21° tall, and the physically large numerals were 0.92° wide × 1.84° tall. To reduce shape differences between digits, we constructed all digits from line segments, as can be seen in the screenshots in Figure 1. In each display, the target was numerically and physically unique. For example, if the distractors' hundreds digits were 8s and 9s, the target's hundreds digit was a 2 or 3. Also, if the distractors were physically large, the target was physically small. The target appeared in one of four quadrants (upper right, lower right, upper left, or lower left).

Procedure

The experiment began with participants reading instructions presented on a series of screens; each screen advanced to the next when participants clicked a button labeled "next." After reading the instructions, participants were presented with a series of visual displays. Each display remained visible until participants reported the target's location by pressing one of two keys. To indicate that the target was on the right side of the display, they pressed the "/" key, and to indicate that it was on the left, they pressed the "z" key. The time between the onset of the display and the participants' keypress was recorded as their RT for that trial. When participants pressed the key that indicated



the wrong side of the display, the program paused for one second, during which the word “Incorrect” appeared in the center of the screen.

In the first block, participants were instructed to find the item that was either physically larger or smaller than all the other items. When the first block ended, the program invited participants to take a short break for as long as they wished, then to click a button labeled “Continue” when they were ready to begin the second block. During the break, participants were instructed to search for the item that was either numerically larger or smaller than all the other items for the remainder of the experiment. Because the target was numerically and physically unique in every display, the displays were the same in both blocks.

In each block, participants were exposed to every combination of target’s numerical size, target’s physical size, target quadrant, number of display items (five, seven, or nine), and target’s hundreds digit (2 or 3 for numerically small targets, 8 or 9 for numerically large targets) in random order for a total of (2 x 2 x 4 x 3 x 2 =) 96 experimental trials in each block. In addition, the first six trials overall and the first six trials after the break were practice, for a total of (6 + 96 + 6 + 96 =) 204 trials, requiring about 15 minutes to complete.

Results

The results from two participants were excluded from analysis because their mean RTs were greater than the mean of the other participants’ RTs plus two standard deviations. The mean correct RTs for the remaining participants (depicted in Figure 2 and summarized in Table 1) were analyzed in a four-way Analysis of Variance with the number of display items, attended feature, numerical size, and physical size as within-subjects factors. Because the early interaction model predicts that RTs should be just as fast in the second block when participants attended to numerical size as in the first block when they attended to physical size, whereas the late interaction model predicts that RTs should be slower in the second block than in the first, the most relevant result was the main effect of attended feature. Furthermore, the early interaction model predicts that the slope of RT as a function of the number of display items should be the same in both blocks whereas the late interaction model predicts that RT slopes should be steeper in the second block. Thus, the second most relevant result was the interaction between attended feature and number of display items. Finally, given that the presence of an SCE

in visual search supports the late selection model, the interaction between numerical and physical size indicates whether the SCE was present. In our description of the results below, we present the most relevant results first, followed by results that were peripheral to the early and late interaction models.

Search Speed and Slope

We had hypothesized that instructing participants to attend to physical size in the first block would eliminate the RT difference between attended feature conditions. Our hypothesis was not supported. The main effect of attended feature,

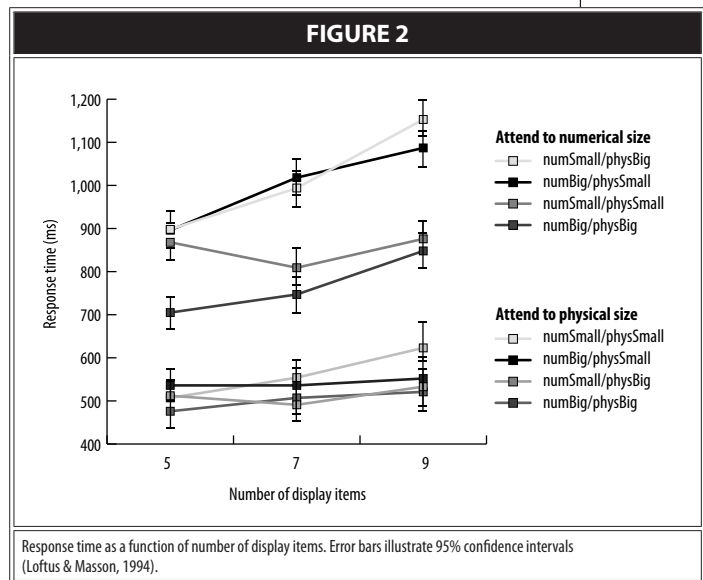


TABLE 1

Mean Response Times (milliseconds)

	Number of Display Items		
	5	7	9
Attend to Numerical Size			
numSmall/physBig	898.16	994.50	1,153.87
numBig/physSmall	896.56	1,018.36	1,087.65
numSmall/physSmall	868.01	809.37	876.78
numBig/physBig	705.80	747.50	848.70
Attend to Physical Size			
numSmall/physBig	512.13	491.79	533.22
numBig/physSmall	536.26	536.05	552.47
numSmall/physSmall	507.70	554.44	623.35
numBig/physBig	476.18	507.01	521.03

$F(1, 14) = 96.40, p < .001, \eta_p^2 = .88$, indicates that responses were faster when participants attended to physical size in the first block than when they attended to numerical size in the second block. The observed difference in RT supports the late interaction model of the SCE.

The main effect of the number of display items, $F(2, 28) = 11.40, p < .001, \eta_p^2 = .57$, shows that RT increased with the number of display items, as is common in visual search experiments. The interaction between attended feature and number of display items, $F(2, 28) = 3.77, p = .037, \eta_p^2 = .22$, shows that the slopes of RT as a function of the number of display items were steeper when participants attended to numerical size in the second block than when they attended to physical size in the first block. The mean slopes were 37 ms/item when participants attended to numerical size, 12 ms/item when participants attended to physical size.

Size Congruity Effect

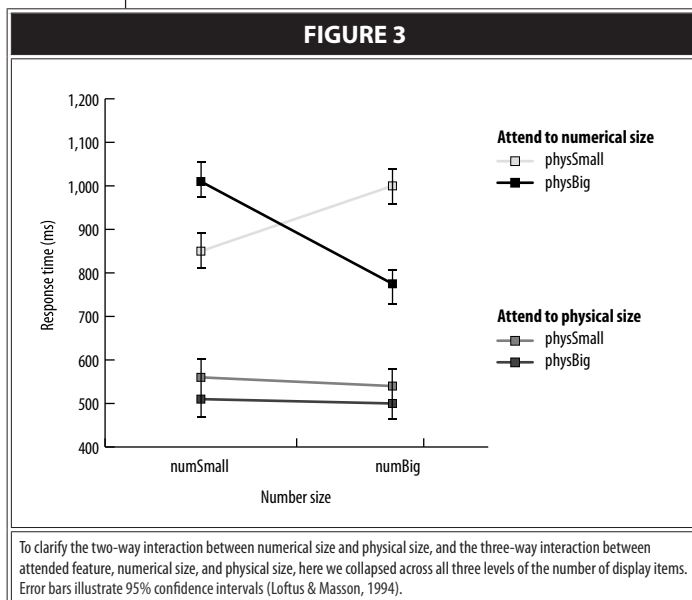
Because the two-way interaction between numerical and physical size is not readily apparent in Figure 2, we collapsed across all three levels of display size in Figure 3. The interaction between numerical size and physical size, $F(1, 14) = 50.06, p < .001, \eta_p^2 = .79$, shows that responses were faster when numerical and physical sizes were congruent than when they were incongruent. As can be seen in Figure 3, the SCE appears to be larger when participants attended to numerical size in the second

block than when they attended to physical size in the first block; there is a clear cross-over interaction when participants attended to numerical size but not when they attended to physical size. The larger SCE when participants attended to numerical size than when they attended to physical size was confirmed by the three-way interaction between attended feature, numerical size, and physical size, $F(1, 14) = 56.88, p < .001, \eta_p^2 = .81$. Simple interaction analysis verified that the two-way interaction between physical size and numerical size was larger when participants attended to numerical size in the second block, $F(1, 14) = 53.71, p < .001, \eta_p^2 = .79$, than when they attended to physical size in the first block, $F(1, 14) = 4.19, p = .060, \eta_p^2 = .23$.

Results Peripheral to the Early and Late Interaction Models

The main effect of physical size, $F(1, 14) = 8.61, p = .012, \eta_p^2 = .40$, shows that search was faster for physically large targets compared to physically small targets. As can be seen in Figure 3, this effect appears to be driven primarily by responses in the first block, when participants attended to physical size. Because all digits were made from white line segments against a black background, physically larger targets were brighter and, therefore, captured attention more than physically smaller and dimmer targets (Braun, 1994; Nothdurft, 2006; Proulx, 2007; Proulx & Egeth, 2008). Apparently, the participants' top-down intention to search for physical size combined with the bottom-up salience of the physically large items enabled them to find the larger items more quickly than the smaller items (Kiss & Eimer, 2011). Although the main effect of physical size is primarily driven by responses in the first block (see Figure 3), responses in the second block for numerically and physically small targets that were slower compared to numerically and physically large targets also seems to contribute. In turn, slow responses for numerically and physically small targets in the second block seem to result from slow responses for numerically and physically small targets for displays containing five items, as can be seen in Figure 2. This data point seems to be anomalous and we have no explanation for why it is slow. Not only does it contribute to the main effect of physical size, but it also seems to have induced an unexpected four-way interaction.

There was a significant four-way interaction between the number of display items, attended feature, numerical size, and physical size, $F(2, 28) = 11.71, p < .001, \eta_p^2 = .47$. A four-way interaction



can be difficult to interpret. We think it indicates that the simple three-way interaction between the number of display items, numerical size, and physical size when participants attended to numerical size was larger than the simple three-way interaction when participants attended to physical size. This is not to say that the overall three-way interaction was significant (it was not, $p = .37$), but rather that the difference between the simple three-way interactions was significant. As can be seen in Figure 2, the three-way interaction when participants attended to numerical size seems to indicate that RTs were steeper for incongruent targets than for congruent targets. In turn, the flatter slopes for congruent targets seems to be driven primarily by the slow RT for numerically and physically small targets when there were five display items. As already mentioned, we have no explanation for this anomalous data point, and thus we believe the four-way interaction is itself anomalous. None of the other main effects or interactions were significant, all p s > .05.

Discussion

Responses were slower during the second block than during the first block. Apparently, the fast search during the first block failed to prime participants to search for the physically unique item during the second block. This does not support our hypothesis, but it does support the late interaction model, which is consistent with a growing number of studies that are incompatible with the early interaction model (Antoine & Gevers, 2016; Arend & Henik, 2015; Cohen Kadosh, Gevers, & Notebaert, 2011; Faulkenberry et al., 2016; Namdar, Ganel, & Algom, 2018; Santens & Verguts, 2011; Sobel, Puri, Faulkenberry, & Dague, 2017). Nevertheless, our failure to prime participants to attend to physical size is inconsistent with previous studies that did manage to prime participants to attend to locations and features that would optimize search efficiency (Chun & Nakayama, 2000; Olds & Fockler, 2004; Sobel et al., 2007). Perhaps visual priming can induce attention to disengage from one visual location or feature but cannot induce attention to disengage from a conceptual feature such as numerical size. Future research is needed to find out why participants are less able to disengage their attention from a conceptual feature compared to a visual feature or if an alternative explanation better explains our failure to prime participants to attend to physical size when instructed to attend to numerical size.

Not only were responses slower in the second

block, but the slopes of RT as a function of the number of display items were also steeper. In visual search experiments, the slope of RT as a function of the number of display items is typically interpreted as an index of search efficiency (Wolfe, 1998), with flat slopes indicating relatively efficient search and steeper slopes indicating relatively inefficient search. The flat slopes in the first block suggest that participants could rely on the visually salient physical size to segregate the target from the distractors, whereas the steeper slopes in the second block suggest that participants serially processed more than just one item before responding. This is consistent with Wolfe and Horowitz's (2004) argument that semantic associations are not guiding features in visual search and also shows that numerical and physical inhabit different mental representations during selection stage, as in the late selection model but not the early selection model.

Another result that deserves notice is the asymmetrical SCE, which was larger when participants searched for the item with unique numerical size than when they searched for the item with unique physical size. Although this asymmetry replicates previous studies (Sobel et al., 2016; Sobel & Puri, 2018), its cause remains unclear. One possibility is that numerical and physical size are processed at different speeds. Whereas physical size can be directly extracted from a visual stimulus, determining a digit's numerical size requires the extra step of connecting the symbol to its associated numerical size in memory (Lupyan, Thompson-Schill, & Swingle, 2010). Thus, incongruent physical size has more of an opportunity to interfere with numerical size than vice versa, giving rise to a larger SCE for participants instructed to search for the numerically unique item (Schwarz & Ischebeck, 2003).

However, one problem with the processing speed explanation for the asymmetrical SCE is that our results invert the asymmetry in Schwarz and Ischebeck (2003). That is, responses were faster and the SCE was smaller when participants attended to physical size in our experiment, but when participants attended to numerical size in Schwarz and Ischebeck's. Our results imply that physical size is processed more quickly whereas theirs suggest that numerical size is processed more quickly. An alternative possibility from the classic word-color Stroop (1935) literature emphasizes the compatibility between the attended feature and the task (Blais & Besner, 2006). The traditional Stroop task entails identification (of the target's meaning or color), which is more compatible with semantic processing,

whereas a localization task (as in our experiment) is more compatible with visual processing. According to the strength-of-association account, the feature that is strongly associated with the task interferes with the weakly associated feature more than vice versa. The task in Schwarz and Ischebeck was a traditional two-item numerical comparison task, which may be analogous with an identification task. Thus, the asymmetry may be inverted because their task is more strongly associated with semantic processing, whereas ours is more strongly associated with visual processing. Future experiments could explore whether asymmetrical SCE is attributable to speed of processing or strength of association.

Limitations

A limitation of our experiment is that we revealed just one single piece of evidence supporting late selection. Nevertheless, as noted above, this single piece of evidence provides converging evidence with numerous other recent studies that support the late selection model. Another limitation is that an anomalous data point (RTs for numerically and physically small targets in displays containing five items when participants attended to numerical size) seemed to induce an unexpected four-way interaction and contributed to the main effect of physical size. Although the RT advantage for larger items could be expected when participants attended to physical size, we have no explanation for why there would have been an advantage when participants attended to numerical size.

Conclusions

Because the SCE results from the interaction between a semantic feature (numerical size) and a visual feature (physical size), it is a descendent of the classic word-color Stroop (1935) effect. Indeed, the size congruity effect is often called the numerical Stroop effect (e.g., Dadon & Henik, 2017). In the Stroop literature, word meaning and color are typically presumed to be processed in separate systems (Blais & Besner, 2006). Thus, our findings that support the late interaction model converge not just with other recent SCE studies, but more broadly with the classic word-color Stroop effect.

References

- American Psychological Association. (2017). *Ethical principles of psychologists and code of conduct*. Retrieved from <http://www.apa.org/ethics/code>
- Antoine, S., & Gevers, W. (2016). Beyond left and right: Automaticity and flexibility of number-space associations. *Psychonomic Bulletin and Review*, 23, 148–155. <http://dx.doi.org/10.3758/s13423-015-0856-x>
- Arend, I., & Henik, A. (2015). Choosing the larger versus choosing the smaller: Asymmetries in the size congruity effect. *Journal of Experimental*

- Psychology: Learning, Memory, and Cognition*, 41, 1821–1830. <http://dx.doi.org/10.1037/xlm0000135>
- Bausell, R. B., & Li, Y. F. (2002). *Power analysis for experimental research: A practical guide for the biological, medical, and social sciences*. Cambridge, United Kingdom: Cambridge University Press.
- Besner, D., & Coltheart, M. (1979). Ideographic and alphabetic processing in skilled reading of English. *Neuropsychologia*, 17, 467–472. [http://dx.doi.org/10.1016/0028-3932\(79\)90053-8](http://dx.doi.org/10.1016/0028-3932(79)90053-8)
- Blais, C., & Besner, D. (2006). Reverse Stroop effects with untranslated responses. *Journal of Experimental Psychology: Human Perception and Performance*, 32, 1345–1353. <https://doi.org/10.1037/0096-1523.32.6.1345>
- Braun, J. (1994). Visual search among items of different salience: Removal of visual attention mimics a lesion in extrastriate area V4. *The Journal of Neuroscience*, 14, 554–567. <http://dx.doi.org/10.1523/JNEUROSCI.14-02-00554.1994>
- Chun, M. M., & Nakayama, K. (2000). On the functional role of implicit visual memory for the adaptive deployment of attention across scenes. *Visual Cognition*, 7, 65–81. <https://doi.org/10.1080/135062800394685>
- Chun, M. M., & Wolfe, J. M. (1996). Just say no: How are visual searches terminated when there is no target present? *Cognitive Psychology*, 30, 39–78. <http://dx.doi.org/10.1006/cogp.1996.0002>
- Cohen Kadosh, R., Gevers, W., & Notebaert, W. (2011). Sequential analysis of the numerical Stroop effect reveals response suppression. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 37, 1243–1249. <http://dx.doi.org/10.1037/a0023550>
- Dadon, G., & Henik, A. (2017). Adjustment of control in the numerical Stroop task. *Memory and Cognition*, 45, 891–902. <http://dx.doi.org/10.3758/s13421-017-0703-6>
- Dukewich, K. R., & Klein, R. M. (2009). Finding the target in search tasks using detection, localization, and identification responses. *Canadian Journal of Experimental Psychology/Revue Canadienne De Psychologie Experimentale*, 63, 1–7. <http://dx.doi.org/10.1037/a0012780>
- Faulkenberry, T. J., Cruise, A., Lavro, D., & Shaki, S. (2016). Response trajectories capture the continuous dynamics of the size congruity effect. *Acta Psychologica*, 163, 114–123. <http://dx.doi.org/10.1016/j.actpsy.2015.11.010>
- Kiss, M., & Eimer, M. (2011). Attentional capture by size singletons is determined by top-down search goals. *Psychophysiology*, 48, 784–787. <http://dx.doi.org/10.1111/j.1469-8986.2010.01145.x>
- Krause, F., Bekkering, H., Pratt, J., & Lindemann, O. (2017). Interaction between numbers and size during visual search. *Psychological Research*, 81, 664–677. <http://dx.doi.org/10.1007/s00426-016-0771-4>
- Loftus, G. R., & Masson, M. J. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin and Review*, 1, 476–490. <http://dx.doi.org/10.3758/BF03210951>
- Lupyan, G., Thompson-Schill, S. L., & Swingle, D. (2010). Conceptual penetration of visual processing. *Psychological Science*, 21, 682–691. <http://dx.doi.org/10.1177/0956797610366099>
- Namdar, G., Ganel, T., & Algom, D. (2018). The size congruity effect vanishes in grasping: Implications for the processing of numerical information. *Scientific Reports*, 8, 2723. <http://dx.doi.org/10.1038/s41598-018-21003-x>
- Nothdurft, H. C. (2006). Saliency-controlled visual search: Are the brightest and the least bright targets found by different processes? *Visual Cognition*, 13, 700–732. <http://dx.doi.org/10.1080/13506280544000237>
- Olds, E. S., & Fockler, K. A. (2004). Does previewing one stimulus feature help conjunction search? *Perception*, 33, 195–216. <http://dx.doi.org/10.1068/p5162>
- Proulx, M. J. (2007). Bottom-up guidance in visual search for conjunctions. *Journal of Experimental Psychology: Human Perception and Performance*, 33, 48–56. <http://dx.doi.org/10.1037/0096-1523.33.1.48>
- Proulx, M. J., & Egeth, H. E. (2008). Biased competition and visual search: The role of luminance and size contrast. *Psychological Research*, 72, 106–113. <http://dx.doi.org/10.1007/s00426-006-0077-z>
- Reike, D., & Schwarz, W. (2017). Exploring the origin of the number-size congruency effect: Sensitivity or response bias? *Attention, Perception, and Psychophysics*, 79, 383–388. <http://dx.doi.org/10.3758/s13414-016-1267-4>
- Risko, E. F., Maloney, E. A., & Fugelsang, J. A. (2013). Paying attention to attention: Evidence for an attentional contribution to the size congruity effect. *Attention, Perception, and Psychophysics*, 75, 1137–1147. <https://doi.org/10.3758/s13414-013-0477-2>
- Santens, S., & Verguts, T. (2011). The size congruity effect: Is bigger always more? *Cognition*, 118, 92–110. <http://doi.org/10.1016/j.cognition.2010.10.014>

- Schwarz, W., & Heinze, H. J. (1998). On the interaction of numerical and size information in digit comparison: A behavioral and event-related potential study. *Neruopsychologia*, *36*, 1167-1179.
[http://dx.doi.org/10.1016/S0028-3932\(98\)00001-3](http://dx.doi.org/10.1016/S0028-3932(98)00001-3)
- Schwarz, W., & Ischebeck, A. (2003). On the relative speed account of number-size interference in comparative judgments of numerals. *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 507-522. <http://dx.doi.org/10.1037/0096-1523.29.3.507>
- Sobel, K. V., Gerrie, M. P., Poole, B. J., & Kane, M. J. (2007). Individual differences in working memory capacity and visual search: The roles of top-down and bottom-up processing. *Psychonomic Bulletin and Review*, *14*, 840-845. <http://dx.doi.org/10.3758/BF03194109>
- Sobel, K. V., & Puri, A. M. (2018). Size congruity influences visual search via the target template. *Acta Psychologica*, *183*, 66-74. <http://dx.doi.org/10.1016/j.actpsy.2018.01.003>
- Sobel, K. V., Puri, A. M., & Faulkenberry, T. J. (2016). Bottom-up and top-down attentional contributions to the size congruity effect. *Attention, Perception, and Psychophysics*, *78*, 1324-1336. <http://dx.doi.org/10.3758/s13414-016-1098-3>
- Sobel, K. V., Puri, A. M., Faulkenberry, T. J., & Dague, T. D. (2017). Visual search for conjunctions of physical and numerical size shows that they are processed independently. *Journal of Experimental Psychology: Human Perception and Performance*, *43*, 444-453. <http://dx.doi.org/10.1037/xhp0000323>
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643-662. <http://dx.doi.org/10.1037/h0054651>
- Wolfe, J. M. (1998). Visual search. In H. Pashler (Ed.), *Attention* (pp. 13-73). East Sussex, UK: Psychology Press.
- Wolfe, J. M., & Horowitz, T. S. (2004). What attributes guide the deployment of visual attention and how do they do it? *Nature Reviews Neuroscience*, *5*, 1-7. <http://dx.doi.org/10.1038/nrn1411>

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