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Telling Things Apart: The Distance Between Response Keys Influences Categorization Times

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Abstract

People use spatial distance to talk and think about differences between concepts, and it has been argued that using space to think about different categories provides a scaffold for the categorization process. In the current study, we investigated the possibility that the distance between response keys can influence categorization times in binary classification tasks. In line with the hypothesis that distance between response keys can facilitate response selection in a key-press version of the Stroop task, our results showed that responses on incongruent Stroop trials were significantly facilitated when participants performed the Stroop task with response keys located far apart, compared with when they performed the task with response keys located close together. These results support the idea that the spatial structuring of response options facilitates categorizations that require cognitive effort, and that people can incorporate environmental structures such as spatial distance in their thought processes. Keeping your hands apart might actually help to keep things apart in your mind.

Keywords

spatial cognition, conceptual thought, binary categorizations, embodiment

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When people use gestures to express the differences between two categories, they often hold their hands apart (Calbris, 2008). This spatial structuring of distinct categories is underlined by metaphors such as "on the one hand, . . . and on the other hand." Research shows that people use space not only to represent categorical differences for communicative purposes, but also to structure their own thoughts (Cienki & Müller, 2008; Goldin-Meadow, 2003; Hostetter & Alibali, 2008). Using space as a tool for thought is an exploitation of concrete environmental structures to support cognition (Clark & Chalmers, 1998; Kirsh, 1995) and can help to reduce cognitive load during difficult tasks (see Goldin-Meadow & Beilock, 2010). Concrete space can be used to group and categorize items, and it has been argued that such use of space can provide a scaffold for the categorization process (Clark, 2008). Therefore, keeping one's hands apart might actually help to keep things apart in one's mind.

Following this logic, we aimed to test the idea that space is used to structure response options in binary classification tasks. Such tasks are among the most widely used experimental methodologies in psychological research. In these tasks, participants typically classify a stimulus into one of two categories (e.g., categorizing the color of letter strings as red or blue) by pressing a response key on the left or on the right. Despite the overwhelming number of studies that have used binary classification tasks, the distance between the left and right keys in these paradigms has not been taken into account as a variable that might influence task performance.

We tested the hypothesis that concrete spatial distance facilitates the categorization process in a binary classification task by examining whether categorization times were influenced by the distance between the response keys. According to our reasoning, when two response keys represent two different categories, the perceptual distance between these two locations can be used to keep the response options apart in thought (Clark, 2008). Consequently, if the keys are further apart, it may be easier to determine that a stimulus belongs to the

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category represented by one hand rather than to the category represented by the other hand. Thus, we propose that a greater distance between response keys facilitates response selection in binary speeded classification tasks by making it easier to select one of two response options for a given stimulus. Because extending the categorization process to include spatial information is thought to reduce the complexity of the task (Kirsh, 1995) and appears to free mental resources (Goldin-Meadow, 2003), the benefit of structuring response options in space should be more apparent when categorizations require more cognitive effort.

Method

To examine whether distance between response keys would facilitate binary categorizations, we asked participants to perform two key-press versions of the Stroop color interference task (MacLeod, 1991; Stroop, 1935). The Stroop (1935) effect is one of the most robust interference effects in psychological research: Responses for words written in a specific color (e.g., red) are faster when the word meaning is congruent with the color (e.g., the word *red* written in red) or neutral (e.g., the letter string *XXXX* written in red) than when the word meaning is incongruent with the color (e.g., the word *blue* written in red). We used a two-color version of the Stroop task in which participants made manual binary categorizations of red and blue stimuli.

The response keys were located far apart during one block of the Stroop task and close together during the other. Correct responses on incongruent trials in a Stroop task require more cognitive control than correct responses on congruent or neutral trials (e.g., Jostmann & Koole, 2007; Kane & Engle, 2003). If the possibility of structuring response options in space facilitates the categorization process (Clark, 2008; Goldin-Meadow & Beilock, 2010; Kirsh, 1995), our reasoning suggests that greater distance between response keys will especially facilitate responses on incongruent (compared with congruent and neutral) Stroop trials.

Participants and design

Forty-one students from a Dutch university (23 females, 18 males; mean age = 21 years) performed the Stroop task in two blocks: one with response keys located close together (close condition) and one with response keys located far apart (far condition). Participants were randomly assigned to one of the two block orders (far-close vs. close-far).

Task

The materials and procedure were identical to those of Jostmann and Koole (2007). In each trial, a letter string was presented in the center of a computer screen. This letter string was the Dutch word *rood* ("red"), the Dutch word *blauw* ("blue"), or a series of *X*s (*XXXX*). All strings were presented in a blue or red font. Participants were instructed to ignore the meaning of the letter strings and to categorize the stimuli according to their color. Each trial started with a 200-ms blank screen, followed by a 500-ms fixation cross, and then the stimulus, which remained on the screen until a response was registered. Each block contained 10 congruent trials (*rood* in red or *blauw* in blue), 10 neutral trials (*XXXX* in red or blue), and 10 incongruent trials (*rood* in blue or *blauw* in red). Participants were asked to respond as quickly and accurately as possible, and to keep their left and right index fingers on two keys of a standard PC keyboard throughout the task.

In the close condition, the adjacent keys "K" and "L" were used to categorize the stimuli. In the far condition, the "S" and "5" (on the number pad) keys were used. During the Stroop task, the category labels and response keys (e.g., "S = rood, 5 = blauw") were displayed on the bottom of the screen in black.

Results

Block order did not influence reaction times and is not discussed further. Response latencies (in milliseconds) averaged separately for each trial type and block were submitted to a 3 (trial type: congruent vs. incongruent vs. neutral; within subjects) × 2 (condition: close vs. far; within subjects) repeated measures analysis. A standard Stroop effect was observed, as indicated by a main effect of trial type, $F(2, 78) = 16.64$, $p < .001$, $\eta_p^2 = .30$. As predicted, the analysis also revealed an interaction between trial type and condition, $F(2, 78) = 3.16$, $p < .05$, $\eta_p^2 = .07$. Paired-samples *t* tests showed that participants responded faster to incongruent trials when the response keys were far apart ($M = 520$, $SD = 186$) than when they were close together ($M = 581$, $SD = 217$), $t(40) = 2.34$, $p = .025$ (see Fig. 1), whereas the difference in key distance did not matter for neutral trials (close: $M = 502$, $SD = 147$; far: $M = 480$, $SD = 150$), $t(40) = 1.00$, $p = .323$, or for congruent trials (close: $M = 484$, $SD = 139$; far: $M = 469$, $SD = 128$), $t(40) = 0.76$, $p = .451$. The main effect of condition did not reach significance, nor were any effects observed in an analysis of error rates.

Discussion

Our study shows that the distance between response keys moderates the strength of the Stroop effect, one of the most prototypical interference effects in psychological research. Being able to structure response options in space facilitates difficult categorizations. These results support the hypothesis that space can be used to structure response categories, thus providing a scaffold for the categorization process (Clark, 2008; Kirsh, 1995).

The current research goes beyond previous work on embodied cognition by showing that even when there are no existing spatial metaphors for the concepts that are being categorized (i.e., there is no conceptual metaphor mapping blue and red onto the horizontal dimension), any two categories are automatically differentiated in space. These results thus reveal the

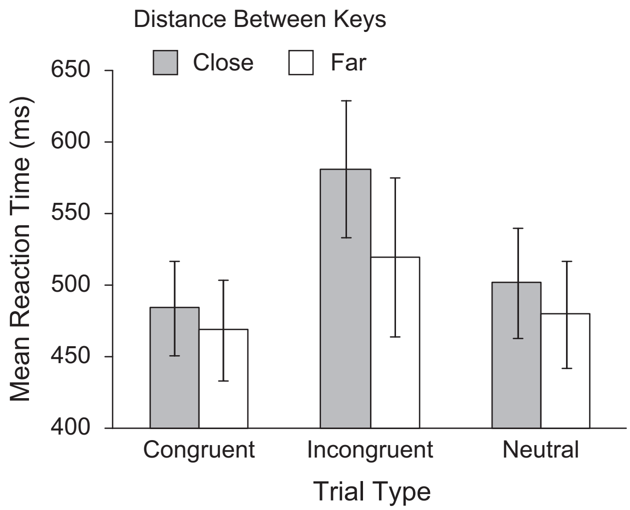

Fig. 1. Mean response latency in the Stroop task as a function of condition (distance between the response keys) and trial type. Error bars represent 95% confidence intervals.

basic human tendency to represent categorical differences in terms of spatial differences. The cognitive process of deciding which response correctly categorizes a stimulus, traditionally regarded as a mental operation dependent on properties of the stimulus and the category, is partly grounded in concrete spatial distance.

The greater distance between response keys in the far condition led to a more pronounced spatial differentiation between the left and right responses than there was in the close condition. Thus, the spatial features of the responses in the far condition (e.g., making a distinct "blue-left" response or a distinct "right-red" response) provided a spatial structuring of the responses that was lacking in the close condition (e.g., making a "blue" or a "red" response). The distinctive spatial features of the response options in the far condition should have facilitated categorizations particularly on incongruent trials, when selecting the correct response key to indicate the color of the stimulus was more difficult because of the interference between the meaning of the stimulus and its color. Such a close relationship between stimulus categorization and response selection seems to be line with the theory of event coding (Hommel, Müsseler, Aschersleben, & Prinz, 2001),[1] which postulates that features of the stimulus (e.g., blue vs. red) and features of the response actions (e.g., left vs. right) are integrated into action plans coded in a shared representational domain. Future research could examine whether a common coding mechanism can indeed account for the observed results.

The interaction between trial type (congruency) and condition (key distance) seems to point toward an effect of key distance on response selection. Still, one might consider the possibility that the distance between response keys influenced the perceived similarity of the stimulus categories or that motor constraints influenced response times in the close condition. Let us discuss these two possibilities briefly. Previous studies inspired by conceptual metaphor theory (Lakoff & Johnson, 1980) examined the "proximity = similarity" metaphor and indeed found that when two stimuli are presented simultaneously on a computer screen, the distance between them influences how conceptually similar they are judged to be (Boot & Pecher, 2010; Breaux & Feist, 2008; Casasanto, 2008). Yet ongoing work has not revealed any effects of the distance between response keys on the perceived similarity of stimuli. For example, whereas people were faster to categorize the brightness of light and dark blue squares when response keys were far apart than when they were closer together, the key-distance manipulation did not influence the perceived similarity of squares of the two colors (Lakens, Schneider, Jostmann, & Schubert, 2011).

A control replication study that we conducted showed that the key-distance effect does not seem to be influenced by motoric or postural constraints in the close condition. In this study, the binary response-selection component was removed from the Stroop paradigm. No effect of key distance on reaction times was found, which indicates that the response-selection component of reaction times, and not the motoric response execution, was facilitated by distance between the keys in our main experiment.[2]

Our findings have a wide range of potential applications. For example, the key-distance effect provides empirical support for the proximity compatibility principle (Wickens & Carswell, 1995). This design principle states that displays relevant for a common task (e.g., speed and altitude meters in airplanes) should be positioned close together so that they can be integrated. Furthermore, children might learn to differentiate between abstract concepts more efficiently if extended embodied-cognition principles were applied in education (see Alibali & Nathan, 2007; Brown, McNeil, & Glenberg, 2009).

Our findings show that the distance between response keys in binary classification tasks, which constitute a cornerstone of empirical psychological research, can unintentionally influence the very way in which people process information. The key-distance effect underlines the idea that people use concrete information as an integral part of cognition, and reveals the automaticity with which people structure their thoughts in space. The distance between your hands can help you tell things apart in your mind.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Notes

1. We thank Art Glenberg for pointing this out to us.
2. The rationale behind this control study was to remove the binary response-selection component from the reaction times while still requiring participants to perform left and right key presses. The Stroop task was adapted into a go/no-go version, in which participants were asked to respond only to words presented in blue (or red; manipulated between participants), by pressing a response key on either the left or the right. The response-selection component was

removed as far as possible by asking participants to press the left and the right keys in alternating order when responding to targets, so that the selection of the left or right response key could be determined before the stimulus was presented. With the exception of these changes, the general procedure and materials were the same as in the main experiment. Participants performed the task twice, with response keys close together ("K" and "L") in one block and with response keys far apart ("S" and "5") in the other. After each block, they were asked how comfortable performing the task had been and whether they could press the response keys smoothly; the response scales ranged from 1 (*not at all*) to 7 (*extremely*).

We found no effect of key distance, trial type, or their interaction on response latencies, nor did participants indicate that they felt less comfortable, or were less able to press the response keys smoothly, in the close condition than in the far condition (all Fs < 1). On the basis of these results, we conclude that participants can press response keys located close together just as fast as response keys located further apart, so it is unlikely that the motor component of response times was influenced by our key-distance manipulation in the main experiment.

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