The effect of time pressure and the spatial integration of the stimulus dimensions on overall similarity categorization.

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Abstract

A free classification study is presented in which the effect of time pressure and the spatial integration of the stimulus dimensions on overall similarity sorting is investigated. A 2 x 2 between-subjects factorial design was employed with the factors being the level of time pressure (high/low) and the spatial integration of the stimulus dimensions (high/low). The results showed, consistent with Milton and Wills (2004), that spatially separable stimuli resulted in a greater level of overall similarity sorting than more spatially integrated dimensions. Furthermore, participants under low time pressure produced a greater level of overall similarity sorting than those under high time pressure, consistent with Milton, Longmore and Wills (2008). Critically, there was also a significant interaction between time pressure and the level of spatial integration, with the integration effect being greater under low time pressure than under high time pressure. These findings provide support for the idea that overall similarity sorting can be the result of an effortful, deliberative process.

Keywords: free classification, overall similarity, unidimensional, time pressure, spatial separability.

Introduction

Categorization is the process by which items encountered in the world are divided into groups of things. Our ability to categorize is so fundamental to our mental life that it is easily overlooked. As an illustration of its importance, in a world of only proper nouns, you could have the concept of "Rover" but not of "Dog", of "Barrack Obama" but not of "President".

The process of categorization must necessarily be highly constrained due to the virtually infinite number of objects we encounter in our everyday environment. One reasonable assumption is that the categories we prefer to create would reflect the underlying structure of objects we encounter outside the laboratory. Over the years there have been several influential theories of natural categories. The "classical" view postulates that natural categories are made up of necessary and jointly sufficient features (e.g., Bruner, Goodnow, & Austin, 1956). If an item has the necessary feature (or features) it can be considered a member of that category regardless of the rest of its properties. In recent times, there has, however, been a growing emphasis on the idea that natural categories are organized around an overall similarity (family resemblance) structure (Rosch & Mervis, 1975). Under this theory, an item does not have to possess any single feature, but as long as it has enough features that are characteristic of that category it can be considered a member of that group. In an overall similarity structure, within-group similarity is maximized and between-group similarity is minimized. One advantage of a family resemblance strategy is that it enables one to make inferences about other properties of an item (e.g., Lassaline & Murphy, 1996). For instance, by classifying an item as a bird, it enables one to infer that it can fly, has feathers, lays eggs, and sings.

Given that the family resemblance theory appears a more compelling account than the classical view, it is surprising that initial studies showed that when people are asked to classify a group of stimuli without any feedback from the experimenter (often known as free classification) they tend to sort by a single dimension (e.g., Ahn & Medin, 1992; Ashby, Queller & Berretty, 1999; Imai & Garner, 1965; Medin, Wattenmaker, & Hampson, 1987). More recent work, however, has shown that overall similarity sorting can be increased by a number of factors including background knowledge (Spalding & Murphy, 1996), stimulus structure (Pothos & Close, 2008), perceptual discriminability (Milton & Wills, 2008), pairwise rather than multiple stimulus comparisons (Regehr & Brooks, 1995), the prior application of an overall similarity sort to different stimuli (Milton &

Wills, 2009), and the spatial separation of the stimulus dimensions (Milton & Wills, 2004).

The focus of the present work is the finding of Milton and Wills (2004) that the level of spatial integration of the stimulus dimensions has a strong influence on the prevalence of overall similarity sorting. Specifically, they investigated factorially the influence that the level of spatial integration and the level of perceptual difficulty had on overall similarity sorting (see Figure 1). They did not find any effect of perceptual difficulty (although see Milton & Wills, 2008), but found that stimuli that were more spatially separable evoked a greater level of overall similarity sorting than stimuli that were more spatially integrated (see also Milton & Wills, 2009).

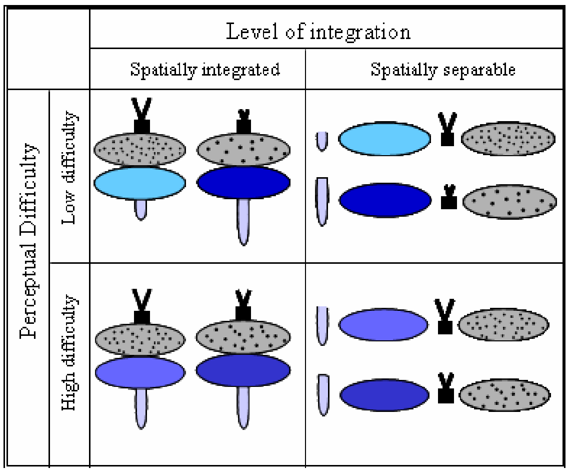

Figure 1. The prototypes of the four stimulus sets used in Experiment 4 of Milton and Wills (2004).

This result was perhaps surprising when one considers previous work which showed that integral stimuli evoked a greater level of overall similarity sorting than separable stimuli (Handel & Imai, 1972; Kemler & Smith, 1979). The explanation often given for this is that separable stimuli allow selective attention and the dimensions can be analysed independently whilst integral stimuli cannot be processed independently of other dimensions and do not allow selective attention (e.g., J.D. Smith & Kemler Nelson, 1984). This makes integral stimuli more conducive to overall similarity responding. Whilst the spatially integrated stimuli used by Milton and Wills (2004) were not integral based on the definition of Garner (1974), integrality-separability has often been considered to be a continuum rather than a dichotomy (Foard & Kemler Nelson, 1984; L.B. Smith & Kemler, 1978). Under these assumptions, one might reasonably have anticipated the spatially integrated stimuli evoking more overall similarity sorting than the spatially separable stimuli. Instead, the opposite occurred.

The explanation that Milton and Wills (2004) gave for their spatial separability effect was that participants sorting by overall similarity were using an effortful and deliberative strategy. This is contrary to the traditional view that overall similarity sorting is the result of a primitive, holistic process in which items are grouped in an automatic and non-deliberative way. The idea that overall similarity sorting is a non-deliberative process has received considerable support in the literature. For instance, Ward (1983) showed that when a time constraint is applied participants grouped items by overall similarity to a greater extent than when under little time pressure (for related findings, see J.D. Smith & Kemler Nelson, 1984; Ward, Foley, & Cole, 1986). Similarly, J.D. Smith & Kemler Nelson (1984) showed that overall similarity sorting was more prevalent under a concurrent cognitive load than under no load and that when participants were asked to respond impressionistically overall similarity sorting was higher than under more standard instructions. This evidence is also complemented by the finding that overall similarity sorting is higher under incidental than intentional learning (Kemler Nelson, 1984) and that children respond by overall similarity to a greater extent than adults (Kemler, 1983, but see Raijmakers, Jansen, & van der Maas, 2004). A similar distinction has also been made in theories of reasoning (e.g., Sloman, 1996) and decision making (Dijksterhuis et al., 2006). Nevertheless, it is unclear how a non-deliberative account could account for the finding that spatially separable stimuli evoked more overall similarity sorting than more spatially integrated stimuli.

As an explanation for their findings, Milton and Wills (2004) proposed that participants sorting by overall similarity used an effortful dimensional summation strategy in which participants consider each dimension in isolation and place the stimulus into the category with which it has most features in common. In other words, according to this account, both overall similarity and unidimensional sorting are based on a deliberative strategy with overall similarity sorting being an effortful and more time consuming approach that makes use of more of the available information. It seems plausible that spatially separating out the dimensions will make them easier to differentiate, making a multidimensional rule strategy easier to apply. In addition, simply separating out the dimensions may make participants aware that they are ignoring relevant information and, consequently, encourage them to make use of more of the information.

Recent work has provided support for Milton and Wills's idea that, at least under certain conditions, overall similarity sorting can be the result of an effortful, deliberative process. Specifically, Milton, Longmore, and Wills (2008) showed, using a match-to-standards procedure, that under a low time constraint participants sort by overall similarity to a greater extent than under a high time constraint and that the imposition of a concurrent load reduced overall similarity responding relative to a no load condition. Furthermore, Wills, Longmore, and Milton (submitted) have shown, using the same procedure, that instructions to categorize in a more deliberative manner increased overall similarity sorting relative to standard instructions, and that both participants with a high working memory capacity and those classified as reflective (rather than impulsive) produced more overall similarity responding. Finally, Milton, Wills, and Hodgson (2009), using fMRI, found greater frontal lobe involvement (which is typically associated with cognitive effort) for overall similarity relative to unidimensional responding.

Whilst Milton and Wills (2004) believed that their spatial separability effect was due to a deliberative overall similarity strategy being more likely for spatially separable than for spatially integrated stimuli this explanation was inevitably post-hoc and there is currently no other evidence that directly supports this claim. The aim of the present study was to seek evidence for this proposal. To do this, we created two sets of stimuli that varied on the level of spatial integration of the dimensions but were in all other respects identical. On the basis of the results of Milton and Wills (2004) we predicted that when participants were given plenty of time to sort the stimuli a spatial separability effect would emerge. That is, participants sorting the spatially separate stimuli would group items by overall similarity more than those sorting the spatially separable stimuli. If, as Milton and Wills (2004) proposed, the spatial separability effect was due to the application of an effortful, deliberative overall similarity strategy, then one would predict that it would be possible to attenuate or even eliminate the effect if participants had limited time in which to categorize the stimuli. This is because participants would then have insufficient time in which to apply the deliberative strategy that is assumed to underlie the separability effect. The present experiment investigates this hypothesis.

Method

Participants

48 undergraduate students from the University of Exeter, aged 18-25, took part in the study. The task was run using E-Prime on a Dell PC with a 22-inch color monitor and a standard computer keyboard. Participants sat approximately 0.5 meters away from the screen.

Stimuli

The stimuli had the same abstract structure as employed by Medin et al. (1987). This category structure is shown in Table 1. The stimulus set consisted of four binary-valued dimensions (D1-D4) and the stimuli were organized around two prototypes each representative of one of the categories. These prototypes were constructed by taking all the positive values on the dimensions for one of the stimuli (1,1,1,1) and all the zero values on the dimensions (0,0,0,0) for the other category. The rest of the stimuli (called one-aways) had three features characteristic of their category and one atypical feature more characteristic of the other category. In total, there were 10 stimuli in the set. Sorting the stimuli by overall similarity maximizes within-group similarities and minimizes between-group similarities.

Table 1: Abstract Stimulus structure

Category A				Category B			
D1	D2	D3	D4	D1	D2	D3	D4
1	1	1	1	0	0	0	0
1	1	1	0	0	0	0	1
1	1	0	1	0	0	1	0
1	0	1	1	0	1	0	0
0	1	1	1	1	0	0	0

Note. Each row (within each category) describes a different stimulus. D = dimension: 1 and o represent the values of each dimension.

The stimuli, whose prototypes are shown in Figure 2, were artificial flowers. The stimuli varied on the number of stamen (few/many), the number of petals (7/8), the length of the stem (short/long), and the shapes of the leaves (pointed/rounded).

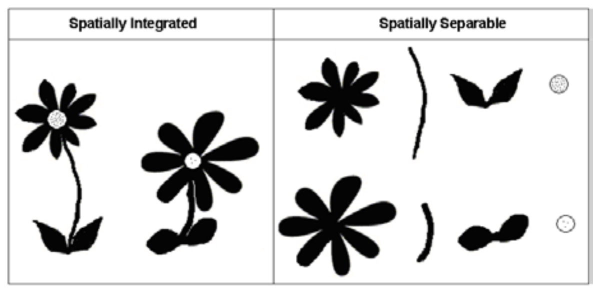

Figure 2. The prototypes of the high spatial integration and the low spatial integration stimulus sets.

Procedure

Participants were randomly allocated to one of the four between-subject conditions. Before the free classification phase, participants were introduced to the stimuli with a pre-sort procedure employed previously by Milton and Wills (2004). Two copies of each of the ten stimuli in the set were spread out randomly in an array. Participants then had to match these stimuli into identical pairs without feedback. If participants made any mistakes, the pairs had to be matched again. The purpose of this task was to ensure participants could fully distinguish the four feature-pairs.

The free classification phase was a slight variation of the match-to-standards task developed by Regehr and Brooks (1995); the task is a computer-based version of the Milton and Wills (2004) task, and it has previously been used in Milton et al. (2008). Participants were informed that they were to take part in a categorization task. They were told that there were many ways in which the stimuli could be split and that there was no one correct answer. They were also told that the groups did not have to be of equal sizes and that they should classify the stimuli in the way that seemed most sensible or natural.

At the start of each trial, participants were presented with the prototypes of category A and category B and were allowed to examine the prototypes for as long as they wished. The category that each prototype represented was fixed across participants. Participants initiated the start of the trial by pressing the space bar. The screen then went blank for 250ms, and this was followed by a central fixation cross for 500ms. One of the stimuli in the set was then presented in the middle of the screen for either 1000ms in the high time pressure condition or 5000ms in the low time pressure condition. Participants were not allowed to respond during this time. The stimulus was then immediately followed by a gray mask which remained on the screen until the participant had made a response (the identical stimulus presentation technique has previously been used by Milton et al., 2008). Participants were required to press the "C" key (which was labeled "A") to indicate the flower belonged to category A or the "M" key (which was labeled "B") to indicate the flower belonged to category B.

Participants were presented with a total of 60 stimuli, in 6 blocks of 10 trials. In each block, each stimulus in the set was presented once in a random order. Participants were given the chance to pause at the end of each block. During this time, they were also asked to write down, as precisely as possible, the way in which they had sorted the stimuli in the previous block.

Analysis of Results

The categories that sorts were placed into were closely modeled on those used in Regehr and Brooks (1995), and identical to those used in Milton and Wills (2004). To be classified as sorting by overall similarity or unidimensionally, the participant's verbal description also had to match their behavioral response.

A unidimensional sort was defined as a sort based on a single dimension of the stimulus. It did not matter which dimension was used as the basis for sorting, providing all the positive valued features for the chosen dimension were in one category and all the zero valued features were in the other category. Participants also had to describe their sort as based on that particular dimension. Sorts were also classified as unidimensional if participants' described their classification as based on a single dimension but there was a solitary error in their classification. In other words, nine of the items were classified on the basis of a single dimension but the other item was placed in the wrong category.

An *overall similarity* sort had the identical structure to that shown in Table 1. In this type of sort, each of the prototypes along with their derived one-aways were placed in separate categories without error. Additionally, participants had to describe their sort as being either based on overall similarity or by indicating that they placed each item into the category with which it had more features in common. Sorts described in this way, but which contained a solitary sorting error, were also classified as overall similarity sorts.

Any other sorts were placed into an *other* category, even if the description given by the participant fitted one of the sort types described above.

Results

For each participant, the sort type for each of the 6 blocks was analyzed separately. These sorts were placed into one of three categories: overall similarity, unidimensional, and other.

The mean proportion of overall similarity, unidimensional, and other sort types for each condition are displayed in Figure 3. For the mean proportion of overall similarity sorts, a 2 (level of time pressure) x 2 (level of dimensional integration) between-subjects ANOVA was conducted. This revealed that there was a significant main effect of time pressure, $F(1, 44) = 46.65$, $p < .001$ indicating that overall similarity sorting was higher under low time pressure than under high time pressure. There was also a significant main effect of spatial integration, $F(1,44) = 5.46$, $p = .024$, indicating that overall similarity sorting was higher for the spatially separable stimuli than for the spatially integrated stimuli. Most important for the current purposes was the significant interaction between time pressure and spatial integration, $F(1,44) = 4.65$, $p = .037$. Pairwise comparisons, assessing this interaction, revealed that there was a significant effect of spatial integration under low time pressure, $t(22) = 2.42$, $p = .024$, but not under high time pressure, $t(22) = .81$, $p = .81$.

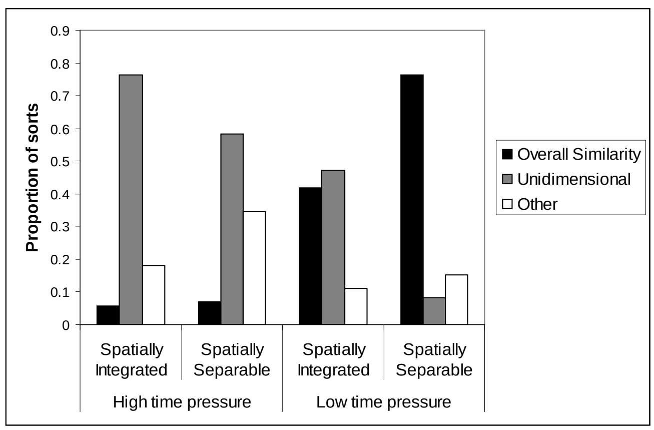

Figure 3. The mean proportion of overall similarity, unidimensional and other sorts for each condition.

For the mean proportion of unidimensional sorts, a similar 2 x 2 between-subjects ANOVA was conducted. This revealed that there was again a significant effect of time pressure, $F(1,44) = 13.63$, $p < .001$, indicating that unidimensional sorting was greater under high time pressure than under low time pressure. There was also a significant effect of spatial integration, $F(1,44) = 7.05$, $p = .011$ indicating that unidimensional sorting was higher for the spatially integrated than the spatially separable stimuli. There was, however, no significant interaction between time pressure and spatial integration for undimensional sorts, F (1,44) = .944, p = .337.

For the mean proportion of Other sorts, a 2 x 2 between subjects ANOVA revealed no significant effect of time pressure, F (1,44) = 2.87, p = .097, spatial integration, F (1,44) = 1.79, p = .188, and no interaction between time pressure and spatial integration, F (1,44) = .64, p = .427.

Discussion

The present study investigated the effect that time pressure has on the prevalence of overall similarity sorting in two stimulus sets that varied in the level of spatial integration of the stimulus dimensions. Specifically, we tested the hypothesis of Milton and Wills (2004) that their finding differential levels of overall similarity sorting depending on the level of spatial integration of the stimulus dimensions was due to an effortful, deliberative, strategy being more likely for spatially separable stimuli. Our results provided support for this explanation. We showed that, consistent with Milton et al. (2008), participants under low time pressure sorted by overall similarity to a significantly greater extent than those under high time pressure. We also found, in line with the results of Milton and Wills (2004), that spatially separable stimuli resulted in a greater level of overall similarity sorting than spatially integrated stimuli. Additionally, and most importantly for the current purposes, there was a significant interaction between time pressure and the level of spatial integration for overall similarity sorting. Specifically, we found that the spatial separability effect was greater under low time pressure than under high time pressure. This was indicated by the fact that the spatially separable stimuli were sorted by overall similarity to a significantly greater extent under low time pressure than the spatially integrated stimuli but that this effect did not approach significance under high time pressure. Indeed, it is striking that for both the spatially integrated and the spatially separable stimulus sets overall similarity sorting was negligible in the high time pressure condition.

Our findings, then, indicate that it is possible to eliminate the spatial integration effect found by Milton and Wills (2004) if one constrains the amount of time available to classify the stimuli. This experiment can therefore be considered as part of a growing body of literature which suggests that overall similarity sorting can be the result of an effortful, deliberative, strategy (Milton et al., 2008; Milton et al., 2009; Wills et al., submitted).

According to this account it should be possible to introduce alternative manipulations that would similarly modulate the spatial separability effect. In particular, if one were to apply a moderate concurrent load (perhaps such as used by Milton et al., 2008) one would also predict, according to a deliberative account, that the spatial separability effect would be reduced relative to a no load condition. Similarly, the separability effect should be larger when one instructs participants to sort in a deliberative mindset relative to in a non-deliberative mindset.

Our conclusion that the overall similarity sorting we observed in this study was the result of a deliberative strategy does not, of course, imply that overall similarity classification cannot also be, under certain conditions, due to a non-deliberative strategy. For instance, we have previously provided evidence that non-deliberative overall similarity sorting can be identified using the match-to-standards procedure under a very high time constraint (Milton et al., 2008). One prediction that follows from this is that if a more severe time constraint was applied to the one that we used here then the pattern of results would reverse. That is, at extreme time pressure, overall similarity sorting would be higher for the spatially integrated stimuli than for the spatially separable stimuli. If such a pattern of results were to emerge, this non-monotonic effect of time pressure on the spatial separability effect would provide further evidence for the idea that overall similarity sorting can be the result of both deliberative and deliberative sorting depending on the task conditions.

It is also the case that whilst evidence for deliberative overall similarity sorting in free classification comes from a diverse number of manipulations such as time pressure (Milton et al., 2008), concurrent load (Milton et al., 2008), instructional manipulations (Wills et al., submitted), individual differences measures such as working memory and level of impulsivity (Wills et al., submitted), as well as imaging work (Milton et al., 2009), this evidence has all been found using the match-to-standards procedure (for a discussion of the important impact procedural differences may have on overall similarity sorting, see Milton et al., 2008). There are a number of reasons that make the match-to-standards procedure an ideal technique for this question – for instance, it provides clear and unambiguous identification of both overall similarity and unidimensional sorting and it is also amenable to both types of sorting behavior. However, it is also the case that the evidence in support of non-deliberative processing comes from a broader range of procedures and our result may be specific to the particular task employed (i.e., the match-to-standards procedure). It is therefore important in future work to test the generality of the idea that overall similarity sorting can be the result of a deliberative strategy across a wider range of procedures. This is something that we are currently pursuing.

In conclusion, this study provides support for the hypothesis of Milton and Wills (2004) that their effect of spatial separability on the prevalence of overall similarity sorting was due to the fact that a deliberative strategy was more likely to be applied for the spatially separable than the spatially integrated stimuli. Our finding that overall similarity sorting was modulated by spatial separability under low time pressure but not under high time pressure provides evidence that this effect only occurs when participants have sufficient time in which to apply such an effortful, multidimensional strategy. As such, this study provides further support for the contention that overall similarity sorting can be the result of a deliberative process.

Future research should aim to provide a greater understanding regarding the precise interplay between the deliberative and non-deliberative systems of overall similarity sorting.

Acknowledgments

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