Effects of Danger, Usefulness, and Body-Object Interaction in picture naming

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Several previous studies have shown that the time-course of word recognition is determined in part by an interaction between connotations of Danger and Usefulness. A small, mostly separate literature has investigated the role of Body-Object Interaction (BOI) in lexical processing. BOI is defined as the ease with which one can interact with an object. To date the lexical decision study of Van Havermaet and Wurm (2014) is the only study to include all three of these constructs. Stimuli in the current study were black-and-white line drawings corresponding to the common nouns used by Van Havermaet and Wurm (2014). Participants viewed the stimuli one at a time in a random order and had to name them as quickly as possible. Naming times revealed a significant three-way interaction between Danger, Usefulness, and BOI similar to that found for visual lexical decision: The familiar Danger x Usefulness interaction, observed in many previous studies, was observed only for items relatively lower on BOI. The interaction between semantic and embodied processing variables is not restricted to purely linguistic stimuli.

Keywords: lexical access, picture naming, danger, usefulness, embodiment, body-object interaction, survival processing

The purpose of this study is to explore the relationship between Danger and Usefulness, semantic variables repeatedly found to influence performance on word recognition tasks, and a newer semantic construct specifically developed to capture embodiment in a range of cognitive tasks, Body-Object Interaction (BOI) (Siakaluk, Pexman, Aquilera, Owen, & Sears, 2008a; Siakaluk, Pexman, Sears, Wilson, Locheed, Owen, 2008b).

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Danger and Usefulness

In several studies, evidence of semantic effects has been found early in the process of spoken word recognition. Specifically, it has been shown that the time-course of word recognition is co-determined by an interaction between Danger and Usefulness (Van Havermaet & Wurm, 2014; Witherell, Wurm, Seaman, Brugnone, & Fulford, 2012; Wurm, 2007; Wurm & Seaman, 2008; Wurm & Vakoch, 2000; Wurm, Vakoch, Seaman, & Buchanan, 2004; Wurm, Whitman, Seaman, Hill, & Ulstad, 2007). In these studies, stimulus words were rated on Danger and Usefulness by one group of participants. Different participants subsequently responded to the stimuli in a word recognition paradigm. In each of the studies just mentioned, the slope of the relationship between Danger and reaction times (RTs) was found to depend significantly on Usefulness. Figure 1 shows a general depiction of the interaction: For words rated relatively low on Usefulness, increasing Danger is associated with faster RTs; for words rated higher on Usefulness, increasing Danger is associated with slower RTs. The interaction has been found using the auditory lexical decision task, visual lexical decision task, and auditory word naming. It has even been observed for both auditory and visual processing of pseudowords (Wurm, 2015).

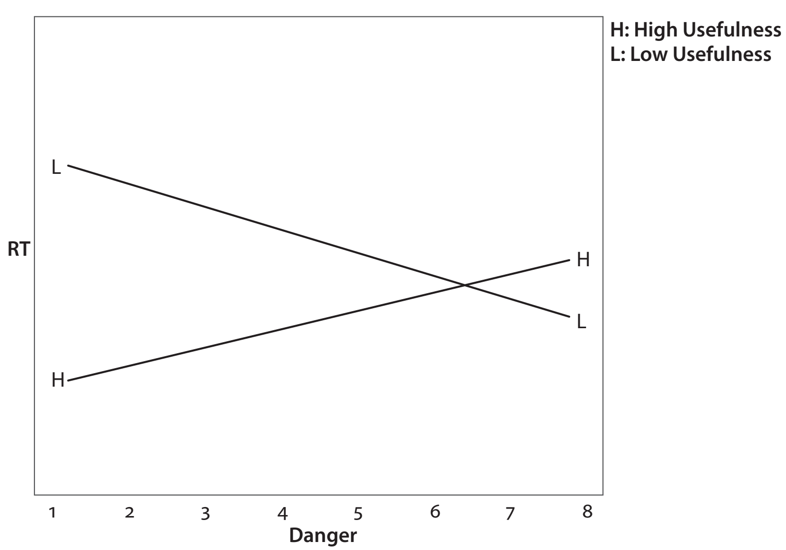

Figure 1. General depiction of the Danger x Usefulness interaction that has been found in several previous studies. "RT" means reaction time. "H" indicates stimuli relatively higher on Usefulness. "L" indicates stimuli relatively lower on Usefulness. See the text for additional details.

To explain this interaction Wurm (2007) proposed a framework in which meaning is extracted via two interacting processes that have different goals and different time-courses. The starting assumption of this framework is that the perceptual-motor system is predisposed to engage in approach behavior for things high on Usefulness and in withdraw behavior for things high on Danger. One of the processes is thought to provide the perceptual system with rough information about Danger and Usefulness, as quickly as possible. Sometimes information from this process alone will be enough for preparations to be made for an appropriate approach or withdraw response, even before a full semantic analysis can be provided by the second, slower process. According to this account, increasing Danger in the context of low Usefulness is unambiguous and leads to faster RTs. Increasing Danger in the context of high Usefulness is associated with slower RTs because things high on both Danger and Usefulness activate both conflicting response patterns.

Embodiment

The foregoing account is embodied, in that it assumes that mental processes are grounded in sensory and motor experiences. Such accounts often emphasize the bidirectional relationship between bodily actions and cognition and/or simulation, the offline activation of all modalities (perceptual, motor, etc.) related to a concept or experience (Barsalou, 1999, 2008; M. Wilson, 2002). Influences of embodiment can be found in many aspects of cognition and behavior, including attitudes, judgments, emotion, distance perception, object preference, and even physical and moral purity (Jostmann, Lakens, & Schubert, 2009; Lee & Schwarz, 2010; Proffitt, Stefanucci, Banton, & Epstein, 2003; Strack, Martin, & Stepper, 1988; Tom, Pettersen, Lau, Burton, & Cook, 1991; Zhong & Leonardelli, 2008; Zhong & Liljenquist, 2006).

There is also evidence of embodiment in language, shown in studies of affective language processing, sentence comprehension, reading, priming, and recognition of single words (Glenberg & Kaschak, 2002; Hauk & Pulvermüller, 2004; Havas, Glenberg, & Rinck, 2007; Meier & Robinson, 2004; Myung, Blumstein, & Sedivy, 2006; Pulvermüller, Härle, & Hummel, 2001; Pulvermüller, Hauk, Nikulin, & llmoniemi, 2005). For instance, in speeded visual and auditory lexical decision tasks, participants responded more quickly to words when primed by a word that shared action characteristics (e.g. target = *typewriter;* prime = *piano*) compared to a prime with few shared action characteristics (e.g. *blanket*) (Myung et al., 2006).

Similarly, judging the sensibility of sentences is influenced by the type of response required. Glenberg and Kaschak (2002) presented participants with sentences that expressed a meaning with a specific direction (toward – put your finger under your nose – or away – close the drawer) and asked them to decide as quickly as possible if the sentence made sense. Responses required either a reach forward or a move toward the body to press the response button. Response directions that were consistent with the sentence direction facilitated sentence comprehension.

Similar kinds of effects can also be observed with affective behaviors and language. In a study focusing on the metaphor concerning good/bad concepts and vertical position, evaluations of positive words were faster when they were presented higher in the visual field, while evaluations of negative words were faster when presented lower. Conversely, after making a speeded evaluation, in an immediate discrimination task requiring a response of p or q, responses were quicker when the correct answer was in the vertical position corresponding to the valence of the previous trial (e.g. correct answer in the "up" position after a positive word) (Meier & Robinson, 2004). As one additional example, when judging the valence and sensibility of sentences, latencies of responses for both judgments were quicker when facial expressions matched the valence of the sentence (Havas et al., 2007).

The idea that sensorimotor information plays a significant role in the processing of language is supported by functional links between motor and language areas of the brain, even showing activation of motor areas specific to word meaning. Transcranial magnetic stimulation (TMS) activating arm motor areas in the left hemisphere resulted in enhanced processing of arm-related action words but not leg-related action words. Likewise TMS of leg motor areas resulted in enhanced processing of leg-related action words but not arm-related action words (Pulvermüller et al., 2005). During a speeded lexical decision task, responses to verbs related to movement of the arms, legs, and face (e.g. talk, pick, walk) produced strongest activation, measured using EEG recordings, in the motor areas related to the body parts responsible for carrying out the action in the verb (Pulvermüller et al., 2001). Similar results were found using a passive reading task measured with fMRI. Action words associated with movement of the arms, legs, and face produced activation in body-part-specific motor areas (Hauk & Pulvermüller, 2004). These studies all point to an influence of sensorimotor information in language processing.

Body-Object Interaction (BOI)

Body-Object Interaction (BOI) is a relatively new dimension that attempts to capture how sensorimotor knowledge affects semantic processing. BOI is defined as the ease or difficulty with which one can physically interact with a concept (Siakaluk, Pexman, Aguilera, Owen, & Sears, 2008a; Siakaluk, Pexman, Sears, Wilson, Locheed, & Owen, 2008b), a definition with an obvious relationship to embodiment.

BOI has been examined in studies using a variety of speeded tasks, including several types of semantic categorization, lexical decision, word and picture naming, and syntactic classification. In most instances, items with high BOI ratings have been shown to produce faster and more accurate responses compared to items with low BOI ratings (Bennett, Burnett, Siakaluk, & Pexman, 2011; Hansen, Siakaluk, & Pexman, 2012; Newcombe, Campbell, Siakaluk, & Pexman, 2012; Siakaluk et al., 2008a, 2008b; Tousignant & Pexman, 2012; Van Havermaet & Wurm, 2014; Wellsby, Siakaluk, Owen, & Pexman, 2011). We will have more to say later about those instances in which a facilitative BOI effect was not observed in these studies.

The facilitative BOI effect has been interpreted as evidence of the role of sensorimotor information in semantic processing. An independent source of converging evidence comes from a study utilizing fMRI (Hargreaves, Leonard, Pexman, Pittman, Siakaluk, & Goodyear, 2012). Processing of words rated high on BOI was associated with greater activation of a sensory association area of the brain related to kinesthetic memory (the supramarginal gyrus of the left inferior parietal lobule) during a semantic categorization task. This provides further evidence that sensorimotor information may be active during semantic processing.

Because of its explicitly embodied nature, BOI provides an intriguing tool with which to test whether the Danger and Usefulness effects in word recognition, described above, require the embodied explanation they have generally been given. Only one study to date has investigated the potential interactions among these three variables. Van Havermaet and Wurm (2014) used visual lexical decision, like several earlier studies on BOI, but they are the only researchers to have also used auditory lexical decision.

Both experiments revealed the expected facilitative main effect of BOI, but interpretation of main effects has to be tempered by consideration of the highest-order interaction present in the data. In the auditory experiment, these were two-way interactions between BOI and Danger, and between BOI and Usefulness. Items with lower BOI values showed stronger Danger and Usefulness effects, while those higher on BOI showed attenuated effects. In the visual experiment, the three-way interaction between BOI, Danger, and Usefulness was significant. Items lower on BOI showed the familiar Danger x Usefulness interaction (see Figure 1), while those higher on BOI did not. Van Havermaet and Wurm (2014) concluded that high BOI attenuates or moderates the effects of Danger and Usefulness, perhaps because it is a stronger effect, or has temporal priority, or both. They also raised the interesting possibility that BOI captures information that is of a qualitatively different type than that captured by Danger and Usefulness ratings. We will return to this point below.

Current study

The current study tests whether BOI interacts with Danger and/or Usefulness in a picture naming study. This unique task provides a bridge between the Danger and Usefulness literature, most of which has used auditory lexical decision, and the BOI literature, nearly all of which has used visual processing (with the Van Havermaet and Wurm (2014) study being a notable exception).

Picture naming is a useful choice of task from the perspective of cognitive models. Theorists need to know whether effects such as these are specifically limited to linguistic stimuli, or whether they reflect more general underlying information-processing mechanisms. Picture naming also seems to give BOI a stronger testing environment, insofar as the link between stimulus and construct is more direct than for a printed or spoken stimulus.

To date only one study has examined BOI in conjunction with the picture-naming task (Bennett et al., 2011), using archival data from the International Picture-Naming Project (Szekely, Jacobsen, D'Amico, Devescovi, Andonova, Herron, et al., 2004). One minor shortcoming of the database approach is noted in Bennett et al. (2011): Several of their items had more than one mean latency listed in that database, so they "simply chose the first mean latency" (p. 1103) to use in their analyses. More importantly for our present purposes, the authors did not examine interactions with other semantic effects such as Danger and Usefulness. The current study will thus provide an additional test of the BOI effect using original data collected specifically for that purpose, and also allow for the assessment of interactions with Danger and Usefulness. Based on the findings of Van Havermaet and Wurm (2014), we hypothesize that items lower on BOI will show the more typical Danger and Usefulness effects.

Preliminary rating study: Picture rating

Norms were not available through existing open sources for all of the pictures, so we gathered them in a preliminary rating study. This also increases the probability that the ratings will be maximally applicable to the local participant population.

Method

Participants

Participants were 71 native speakers of English from the Psychology participant pool. They received extra credit in a psychology class in exchange for their participation.

Stimuli
Black-and-white line drawings on white backgrounds were found that corresponded to the 102 common nouns Van Havermaet and Wurm (2014) used. Thirty-one images were taken from the norming study by Snodgrass and Vanderwart (1980), 15 were taken from the IPNP website (Szekely et al., 2004), and the rest were found through internet image searches. The picture corresponding to *army* was excluded from the naming experiment because of the difficulty in finding a line drawing that sufficiently elicited the desired response.

The Appendix lists the stimuli used, along with the mean rating for each stimulus on Danger, Usefulness, and BOI. BOI values were taken from Van Havermaet and Wurm (2014). Danger and Usefulness values were taken from several previous studies that used subsets of the items (Kryuchkova, Tucker, Wurm, & Baayen, 2012; Witherell, et al., 2012; Wurm, 2007; Wurm & Vakoch, 2000). The distributions of Danger and Usefulness values both had moderate positive skew, so they were log transformed prior to analysis. The mean BOI ratings were positively correlated with log mean Usefulness ($r(99) = 0.52$, $p < .001$) and negatively correlated with log mean Danger ($r(99) = -0.25$, $p < .05$). Log mean Danger and log mean Usefulness were uncorrelated ($r(99) = -0.07$, $p = .48$).

Procedure
All pictures were rated by all participants on visual complexity, familiarity, image agreement (how closely the picture matches participants' mental images), and name agreement as described by Snodgrass and Vanderwart (1980). Name agreement was calculated using the H statistic, a measure that takes into account the proportion of responses for each alternative name (Snodgrass & Vanderwart, 1980). An H value of 0 indicates perfect name agreement and higher values indicate less agreement. The other dimensions were rated on integer scales that ran from 1 to 5, inclusive.

Results and discussion

Means were calculated for each item and used in subsequent analyses. Values for familiarity ranged from 2.55 (*trap*) to 4.78 (*house*), with a mean of 3.81($SD = 0.61$). Values for image complexity ranged from 1.58 (*heart*) to 4.36 (*crow*), with a mean of 3.00 ($SD = 0.61$). Values for image agreement ranged from 2.57 (*hill*) to 4.76 (*tarantula*), with a mean of 3.96 ($SD = 0.42$). Values for H ranged from 0.00 (*apple*) to 3.12 (*lake*), with a mean of .60 ($SD = 0.64$).

Main reaction-time study: Picture-naming method

Method

Participants

Participants were 152 native speakers of English with normal or corrected-to-normal vision, recruited from the Psychology participant pool. They received extra credit in a psychology class in exchange for their participation.

Stimuli

The pictures from the Preliminary Rating Study were used. They were resized (if necessary) so that each was 300x300 pixels.

Procedure

Participants sat approximately 60 cm from the computer screen. They were told to say out loud the name of the pictured object as quickly and accurately as possible. Response time was measured from item onset until the microphone detected a spoken response. The intertrial interval was 1000 msec. Ten practice trials were completed prior to the main experiment.

Data analysis

Participants provided the correct picture name on 70% of the trials.[1] RTs on these trials were retained for analysis, with the exception of RTs faster than 300 msec from acoustic onset (1.3% of the data) or more than 2.5 standard deviations slower than the grand mean (1.6% of the data). A multilevel linear mixed-effects analysis of covariance with participants and items as crossed random factors was used to analyze the RTs (Baayen, Davidson, & Bates, 2008), which were log transformed because of moderate positive skew. Data were analyzed using version 3.0.2 of the R statistical language (R Core Team, 2013) and version 2.0–6 of the *lmerTest* package

1. Picture naming produces higher error rates than word naming, but a 30% error rate is high even in this context. We cannot be sure why it was this high, but to see if the likelihood of an error was related to any of the variables of primary interest in this study, we analyzed the data with a hierarchical generalized linear mixed-effects model. Each trial was coded as a 0 (no error) or a 1 (error), and the model included participants and items as crossed random factors (Baayen, Davidson, & Bates, 2008). Fortunately, the probability of an error was unrelated to BOI, Danger, Usefulness, or any of the possible interactions between those variables (smallest $p = .14$). Thus, although the high error rate represents an unfortunate loss of data, we believe it to be random with respect to the variables of interest in this study.

(Kuznetsova, Brockhoff, & Christensen, 2014). Significance testing in *lmerTest* uses the Satherthwaite approximation for calculating the appropriate degrees of freedom for each test.

The analysis proceeded hierarchically, with the significance of a given effect assessed at the step at which it was entered. Step 1 contained the main effects of interest (Danger, Usefulness, and BOI) along with several control variables. These included the norms collected in the Preliminary Rating Study (i.e., image familiarity, image complexity, image agreement, and name agreement). It also included the control variables used in Van Havermaet and Wurm (2014): word frequency (from the English Lexicon Project Database (Balota, Yap, Cortese, Hutchison, Kessler, Loftis, et al., 2007)), item length, and concreteness (from the MRC Psycholinguistic Database (Wilson, 1988)).

Two-way interactions between BOI, Danger, and Usefulness were entered in a second step of the analysis. The three-way interaction was entered in a final step.

Several variables had moderate positive skew and were log transformed to reduce the effects of atypical outliers (Tabachnik & Fidell, 2007): item length, frequency, Danger, and Usefulness. Concreteness values had mild positive skew and were square-root transformed (Tabachnik & Fidell, 2007). BOI values were suitably normal without any transformation.

All variables (including the log RTs) were transformed to *z*-scores, which means that the coefficients provided by the analysis are standardized (βs) rather than unstandardized (Bs). This allows for direct comparison of the sizes of the effects each variable had, because the coefficients are all on a common scale. It has an added advantage in terms of visually representing the results, as will be seen below.

Results and discussion

Results of the analysis are shown in Table 1. Pictures associated with longer names and those with more complexity had slower RTs. Pictures with higher familiarity, frequency, image agreement, or name agreement had faster RTs (readers should recall that higher values of H indicate *less* name agreement). Of the variables of particular interest, only Usefulness had a significant main effect.

As in both lexical decision experiments of Van Havermaet and Wurm (2014), BOI interacted significantly with Danger. However, any interpretation of this interaction must be qualified in light of the significant three-way interaction between Danger, Usefulness, and BOI.

Table 1. Summary of hierarchical analysis for variables predicting log picture-naming time

Predictor	***β***	**95% *CI***
Step 1		
Log item length	0.029***	[0.012, 0.046]
Item agreement	−0.172***	[−0.193, −0.151]
Name agreement	0.279***	[0.260, 0.298]
Complexity	0.072***	[0.055, 0.090]
Item familiarity	−0.168***	[−0.197, −0.139]
Log word frequency	−0.048***	[−0.070, −0.026]
Square root concreteness	−0.006	[−0.023, 0.010]
BOI	0.016	[−0.007, 0.040]
Log mean danger	0.001	[−0.017, 0.019]
Log mean usefulness	0.034**	[0.012, 0.056]
Step 2		
BOI x danger	0.023*	[0.002, 0.044]
BOI x usefulness	−0.009	[−0.025, 0.007]
Danger x usefulness	−0.006	[−0.031, 0.019]
Step 3		
BOI x danger x usefulness	−0.047***	[−0.066, −0.029]

* $p < .05$.
** $p < .01$.
*** $p < .001$.
Note. The full regression equation from Step 3, used to create Figure 2, was: $Y = 0.022 + 0.038(\text{length}) - 0.187(\text{item agreement}) + 0.275(\text{name agreement}) + 0.076(\text{complexity}) - 0.147(\text{familiarity}) + 0.001(\text{concreteness}) - 0.001(\text{BOI}) + 0.036(\text{Danger}) + 0.001(\text{Usefulness}) + 0.023(\text{BOI x Danger}) + 0.002(\text{BOI x Usefulness}) - 0.014(\text{Danger x Usefulness}) - 0.047(\text{BOI x Danger x Usefulness})$. See the text for additional details.

To understand the nature of this three-way interaction, the full regression equation was plotted four times, with all variables other than Danger, Usefulness, and BOI set to their mean values. Because *z*-scores by definition have a mean of 0, all terms drop out of the equation except BOI, Danger, and Usefulness. Danger was defined as a vector running from −1.78 to 2.25, which were the *z*-scores corresponding to the minimum and maximum values actually observed in the dataset for logged mean Danger. The four computations were defined by high vs. low Usefulness and high vs. low BOI, which in each case was defined as being one standard deviation above or below the mean value in the dataset. Because *z*-scores have a standard deviation of 1, the high and low values become 1 and −1, respectively. The results are shown in Figure 2.

Plotting the Danger x Usefulness interaction for separate values of BOI allows for a direct visual comparison with the results of Van Havermaet and Wurm

(2014). It also allows an easy comparison to the previous research that has found the Danger x Usefulness interaction (Witherell et al., 2012; Wurm, 2007, 2015; Wurm & Seaman, 2008; Wurm & Vakoch, 2000; Wurm et al., 2004, 2007).

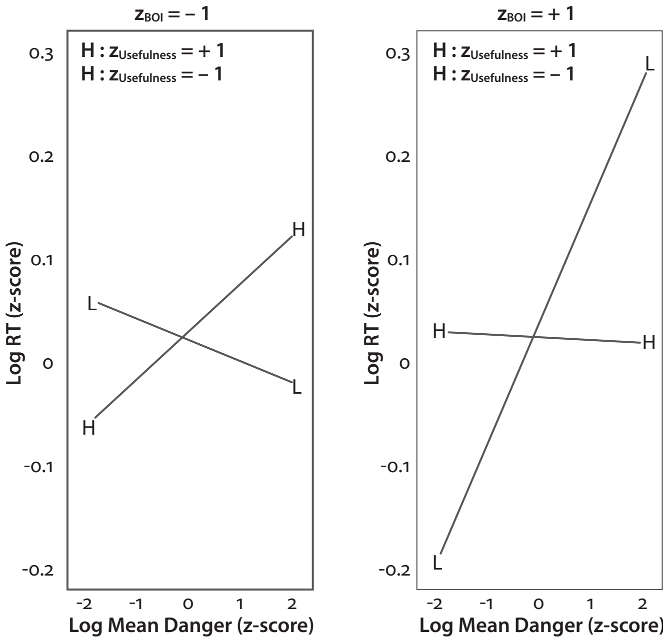

Figure 2. Log RT as a function of Danger, Usefulness, and Body-Object Interaction (BOI), in msec. The left panel plots the full regression equation with BOI set one standard deviation below the mean. The right panel plots the same equation with BOI set one standard deviation above the mean. "H" indicates one standard deviation above the mean on Usefulness. "L" indicates one standard deviation below the mean on Usefulness. The y-axis values, translated back into raw RT, run from roughly 740 to 872 msec. See the text for additional details.

For the left panel, BOI was set to −1. For the right panel, it was set to 1. In both panels, the "L" lines indicate that Usefulness was set to −1, and the "H" lines indicate that Usefulness was set to 1. For items lower on BOI (left panel) the interaction is very similar to that seen in Van Havermaet and Wurm (2014). In the context of items lower on Usefulness, increasing Danger is associated with faster RTs (the "L" line here translates to a 23-msec effect). For items higher on Usefulness, increasing Danger slows them (the "H" line shows a 50-msec effect). This is the pattern shown in Figure 1, which has been found in several previous studies.

For items higher on BOI (right panel), the pattern is nearly the opposite. However, a closer comparison between the current figure and Figure 4 of Van

Havermaet and Wurm (2014) reveals that the slopes for three of the four plotted lines are very similar. The difference is that in the previous visual lexical decision study, performance for items high on BOI and high on Usefulness showed a roughly 33-msec increase as Danger ratings rose from the minimum to the maximum value. In the current study that line is nearly flat (a 2-msec effect; for the sake of completeness, we report the "size" of the effect for the "L" line in the right panel – it shows a 130-msec effect).

We do not have a compelling explanation for this specific aspect of the finding. One possibility has to do with the time-course over which such effects emerge and dissipate – the mean RT in the current picture-naming study was 838 msec, over 50% longer than in Van Havermaet and Wurm's (2014) visual lexical decision experiment. Another possibility has to do with the suggestion by Louwerse and Jeuniaux (2010) that picture stimuli produce stronger semantic effects than word stimuli. One possible interpretation, then, is that the picture stimuli in the current study produced a stronger semantic effect (the Danger x Usefulness interaction for high-BOI items) than did the word stimuli of Van Havermaet and Wurm (2014).

It is worth noting that across all of the studies referenced above, this is the first time this particular pattern has emerged. We therefore think it wise not to speculate too much about why such a specific aspect of the results would differ in just this way. The broad general conclusion is consistent with the visual lexical decision experiment of Van Havermaet and Wurm (2014): Stimuli lower on BOI produced the familiar semantic interaction, while those higher on BOI did not.

One interesting aspect of the Van Havermaet and Wurm (2014) finding that did replicate is the slope reversal of the two "Low Usefulness" lines in Figure 2. Why should that particular relationship depend so strongly on BOI? Examination of the stimuli inhabiting some of the "corners" of the 2x2x2 lexical space suggests one possible interpretation having to do with the interplay between affect and embodiment. In the left panel of Figure 2, pictures low on Danger and Usefulness were of things like *race, hill*, and *flag*. Such stimuli would seem to evoke little to no affective response, and there is also little possibility of physically interacting with them. They produce very average RTs. Remaining in the left panel but moving to the high end of the Danger scale, we have pictures like *bomb, cliff*, and *cannon*. People are a bit faster to name such pictures, perhaps because they create more of an affective response. Even though the possibility of physical interaction remains low, there is little response ambiguity here: The only appropriate response is "withdrawal."

In the other panel of Figure 2, pictures low on Danger and Usefulness are of items such as *key, diamond*, and *pie*. One can physically interact with such things, and again there is no ambiguity about the appropriate response ("approach," in this case). Moving finally to the high end of the Danger scale, we find pictures such as *fork* and *razor*. Here we see some response ambiguity (one gets hurt by interacting with such objects in the wrong way), and correspondingly slow RTs. This account is speculative, and we would have expected this kind of slope for items higher on Usefulness, too. Indeed, that was observed in Van Havermaet and Wurm (2014).

It is also worth noting that because of the correlational structure of the stimulus set, this particular corner of lexical space (i.e., items high on BOI and Danger, but low on Usefulness) was very sparse. Such items' affective/semantic atypicality could conceivably contribute further to the increase in RTs. Whether this is a characteristic of the language, or an accidental characteristic of the stimuli we used, awaits additional research.

General discussion

The current study adds to the literature suggesting that sensorimotor information may be incorporated into semantic representations, while at the same time demonstrating that the findings of Van Havermaet and Wurm (2014) were not due to idiosyncratic characteristics of the lexical decision task. The conclusions reached in the earlier study were largely confirmed here. This is important in light of the many differences in the experimental tasks. In lexical decision the participants simply have to decide if a letter string is a genuine English word, whereas in picture naming the participants have to recognize the picture, retrieve its name from the mental lexicon, formulate the appropriate articulatory plan, and execute that plan. This more complex task produced response times more than 50% longer than the simpler task, but the same broad finding held. It bears repeating here, too, that most previous work on the BOI construct used some variant of semantic categorization, a task quite different from both lexical decision and picture naming. Thus the conclusions are coming to rest on firmer ground.

Wurm and colleagues (2007; Wurm et al., 2007) interpreted the Danger x Usefulness interaction in word recognition as stemming from a response conflict generated during a fast, automatic process that has as its purpose the computation of gross (rather than detailed) survival-relevant information. This information might potentially be used to ready certain behavioral responses even before completion of a second, slower process. This second process interacts with the first, and has as its purpose the full-fledged semantic analysis. The slowing of response times for stimuli high on Usefulness, in the context of higher values of Danger, has been presumed to reflect the simultaneous pre-activation of conflicting approach (high Usefulness) and withdraw (high Danger) responses.

Why, then should the effect only hold for stimuli relatively lower on BOI? This aspect of Van Havermaet and Wurm's (2014) finding was surprising, because previous findings with the slope relationships shown in Figure 1 had been so ubiquitous in previous studies. The current study replicates that finding, and suggests that although BOI was not measured (or even considered) at the time of those earlier studies, perhaps the stimuli just happened to be items relatively lower on BOI. We do not think this likely, because hundreds of different stimuli have been used over the years, with different sampling criteria that ranged from almost completely random (Vakoch & Wurm, 1997) to somewhat more intentional (Wurm & Vakoch, 2000) to exhaustive (Wurm, 2007).

One possible implication of the current study is that the Danger x Usefulness interaction does not require the embodied interpretation it has always been given. It would seem that if that interaction reflected embodiment, it would be strongest for stimuli that are the easiest with which to physically interact (i.e. those higher, not lower, on BOI). Together with Van Havermaet and Wurm (2014), the current study instead supports the tentative hypothesis that two different kinds of information are indexed by the variables under study. “BOI simply indexes the possibility of physical interaction with something, while Danger and Usefulness are defined to have specific relevance to survival processing” (Van Havermaet & Wurm, 2014, p. 16). The current study was not designed to tell us whether that interpretation is right, but this might prove a valuable avenue for future research.

Other avenues are suggested by instances in the small BOI literature in which a facilitative BOI effect was either not observed, or was observed for only some of the stimuli. For example, Newcombe et al. (2012) found a standard (i.e. facilitative) BOI effect in semantic categorization times for concrete nouns, but an inhibitory BOI effect in the categorization times for abstract nouns. Most of the stimuli in the existing studies on Danger and Usefulness have been concrete nouns, but Wurm (2015) found the usual Danger x Usefulness interaction in auditory and visual processing of *pseudowords*, which would seem to be about as far from concrete as any stimuli could be. Even upon participants’ first exposure to a stimulus, and even in the absence of any previously-assigned meaning, the effect is observable. This supports the potential idea of a difference in the kind of information captured by the ratings (perhaps emotional in the case of Danger and Usefulness vs. sensorimotor in the case of BOI).

Tousignant and Pexman (2012) used a variety of semantic categorization tasks. Critical stimuli were a subset of the nouns used by Tillotson et al. (2008) as well as action words such as *jump*. Some participants had to quickly decide “Is it an action?”, some had to decide “Is it an entity?”, and some had to make the joint classification. They found a facilitative BOI effect only when “Is it an entity?” was part of the decision. That is, it did not appear in the “Is it an action?” condition. This suggests that the BOI effect is weaker or absent in verbs, which would make sense given that the entire issue of “possibility of interacting with” seems nonsensical for verbs.

However, Wurm (2007) found a sizable Danger x Usefulness interaction, with the expected slope relationships (cf. Figure 1 of the current study), for nouns, verbs, and adjectives. In addition, Sidhu, Kwan, Pexman, and Siakaluk (2014) developed a BOI-like construct for verbs, which they called *relative embodiment*. They defined it in terms of "how easily an action, state, or relation involves a human body" (p. 38), giving other related characterizations and several examples, in the process of gathering participant ratings of many verbs. In subsequent experiments they found that verbs higher on relative embodiment were processed faster in visual lexical decision, action picture naming, and syntactic classification.

As a final recommendation, we believe it would prove useful to employ a wider variety of research methodologies. Evoked potentials can provide a more fine-grained temporal view of the mental processes involved than can the press of a button or a spoken response (Van Havermaet & Wurm, 2014). No ERP study to date has look at BOI. We might also learn from methodologies that involve physical movement toward or away from a participant's body as part of the required response, such as the classic Chen and Bargh (1999) study that looked at stimulus valence.

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Appendix. Stimuli

Item	Mean BOI rating	Mean danger rating	Mean usefulness rating
angel	2.45	1.18	4.92
apple	5.28	1.35	6.01
arm	5.94	1.79	6.51
axe	4.17	5.08	4.64
bag	4.66	2.23	3.7
ball	5.25	2	3.4
barn	3.92	1.21	4.2
basket	4.72	1.27	4.06
bean	4.6	1.85	5
bear	3.75	4.78	3.7
bench	5.09	1.52	3.26
board	4.25	1.46	2.42
bomb	3.56	7.57	3.35
boot	5.16	1.25	4.65
bottle	5.06	2.57	4.77
bull	3.7	3.93	3.55
bus	4.78	2.42	4.1
cannon	3.49	6.06	3.06
cheese	5	1.54	4.95
choir	3.65	1	3.05
circle	2.66	1.66	3.97
cliff	3.56	4.53	3.66
cotton	4.61	1.32	5.3
crab	3.93	2.84	3.9
crow	3.24	1.98	2.72
devil	2.16	5.62	2.8
diamond	4.61	2.34	3.06
doll	5.15	1.6	2.58
drum	4.73	1.14	3.2
earth	4.83	2.07	7.2
fish	4.57	2.11	6.21
fist	5.48	4.12	4.64
flag	4.26	1.79	2.79
flower	4.87	1.29	4.15
food	6.24	1.78	7.98
fork	5.17	2.45	4.32
gift	4.87	1.42	3.6
girl	5.98	2.3	6.27
globe	3.9	2.19	5.08

Item	Mean BOI rating	Mean danger rating	Mean usefulness rating
guard	3.82	2.5	4.05
hair	6.12	1.14	6.15
hammer	4.87	3.49	4.9
hand	6.19	2.54	6.85
heart	5.08	3.14	7.44
hill	4.22	2.08	4
hook	4.15	4.08	4.17
horn	4.21	2.61	3.09
hospital	4.73	3.71	7.13
house	5.17	2	6.75
jail	3.88	4.42	4.42
jet	3.99	3.08	4.14
key	4.93	1.62	4.06
knife	4.99	6.03	5.84
lake	4.48	2.98	5.72
lamp	4.7	1.63	4.47
lightning	2.6	6.31	2.46
lock	4.42	2.18	4.9
magazine	4.87	1.85	2.69
man	6.07	3.19	6.8
money	5.53	4.84	6.12
nail	5.08	3.41	4.48
napkin	5.02	1.38	3.27
neck	5.56	2	6.85
noose	3.83	5.9	2.82
nun	3.99	1.54	2.98
ocean	4.45	3.75	5.78
owl	3.38	1.87	3.42
paint	4.57	2.14	3.34
pea	4.44	1	4.6
pencil	5.01	2.14	3.95
pie	5.15	1.48	3.5
pin	4.33	2.48	3.06
priest	4.48	2.62	4.01
race	3.63	1.61	4.1
rat	3.74	3.15	2.9
razor	5.18	4.96	3.88
rock	4.6	2.8	4.96
school	4.7	1.39	6.4
shell	4.11	1.88	3.4
skunk	3.58	2.2	2.29

(*continued*)

Item	Mean BOI rating	Mean danger rating	Mean usefulness rating
smoke	4.09	5.62	4.68
spring	3.54	1.48	5.34
stove	4.89	3.31	5.51
string	4.4	2.27	4.1
sun	3.27	3.25	7.35
swan	3.71	1.25	3.3
sword	4.33	5.07	4.73
syringe	4.82	4.95	5.47
tarantula	3.81	5.46	1.93
tiger	3.52	5.27	3.31
torch	3.88	4.3	4.72
trap	3.21	5.04	4.12
trunk	4.13	2.1	3.36
vampire	1.94	3.74	1.8
vest	5	1.58	3.22
volcano	2.74	5.8	3.66
water	6.02	2.06	7.68
week	2.43	1.46	5.79
window	4.45	2.25	4.24
woman	6.08	2.69	6.77
wood	4.54	2.14	6.73

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