A spoke in the wheels for the ‘attentional set’ theory?

The importance of features as a mediator of Inattentional Blindness
Abstract

Inattentional blindness (IB) refers to the phenomenon whereby an individual fails to report an unexpected object or event, when attention is engaged in another task. When given a task, individuals adopt an ‘attentional set’ including their expectations for both physical visual properties (such as shape or colour), and also semantically-related information. Previous studies have shown a strong “category exemplar” effect on IB: when individuals set attention for pictures belonging to a particular semantic category, exemplar words that also belong to that category are detected (Koivisto & Revonsuo, 2007; Tompkins, 2012). We explored how individuals set attention for the category of vehicles to see whether featural properties were also detected. Results suggest that featural properties of the attended category are not salient at a semantic level, although they may guide pre-attentive detection. We discuss these findings in relation to the components of the attentional set, and suggest that although early studies have shown that individuals’ attention could be set for features at a perceptual, physical level (e.g., Most et al., 2001) the individuals’ semantic attentional set may be relatively narrow, exclusive to category exemplars that the individual may expect to see and then name.

Keywords: attention; perception; inattentional blindness; attentional set; semantic categorisation.
Inattentional Blindness (IB; Mack & Rock, 1998) refers to the occasion whereby an individual fails to report an unexpected object, when engaged in a task. Individuals establish an “attentional set”, corresponding to a mental template for the task in relation to what they expect to encounter (Folk, Remington, & Johnston, 1992). For example, if asked to search for a yellow triangle from among shapes, individuals’ attentional set will include information about colour, “yellow”, and shape, “triangular”. Notably, unexpected stimuli that are at odds with the individuals’ attentional set appear to be especially prone to IB.

Simons and Chabris (1999) asked participants to observe a basketball game and count the passes of either a team wearing white clothing, or their opposition wearing black clothing. Surprisingly, 58% of participants counting passes of the team in white did not report a woman in a black gorilla suit walk through the middle of the game, whereas 17% of participants did not detect the gorilla when counting the passes of the team in black. This suggests that the attentional set for the latter group was ‘congruent’ with a predominant feature of the unexpected stimulus (the colour black), permitting detection.

Attentional set theory (e.g., Folk et al., 1992) therefore indicates that the perceptual thresholds of objects vary according to the task-related goals of the observer. The theory is supported by findings of strong interconnectivity between the prefrontal cortex involved in working memory, and occipital visual areas, which can modulate or bias the responsiveness of neurons in visual regions to different, anticipated stimuli (Desimone & Duncan, 1995). Furthermore, distractors in target search paradigms lead to greater interference, attentional capture or noticing rates if similar to the expected stimulus characteristics (Duncan & Humphreys, 1989). Such findings suggest that the attentional set of an individual allows more rapid detection.
of item properties that are congruent with what is expected. There also appears to be a significant advantage in detection and recognition of semantically-related items, suggesting that unexpected stimuli may be processed in terms of their semantic relevance to the attentional set as well as with regards to lower-level properties (Koivisto & Revonsuo, 2007).

Previous IB studies exploring semantic variables have generally investigated whether an unexpected, critical stimulus that has a meaning that is congruent with the attentional set of the participant will capture attention. Koivisto and Revonsuo (2007) manipulated the semantic content of participants’ attentional sets by asking them to view four simple pictures, but attend only to those of a specific category such as ‘animals’. Several trials into the experiment, an unexpected word was presented in the centre of the screen, which was either congruent or incongruent with the attended category. An alternative paradigm presented participants with four words in the primary task, and an unexpected picture in the centre of the screen.

Koivisto and Revonsuo (2007) found that 94% of participants detected the congruent unexpected item, compared to 41% in the incongruent condition. These results provided important evidence that the semantic content of an observer’s task-congruent attentional set is a determinant of IB, as semantically congruent unexpected items were both detected and recognised more frequently than semantically-unrelated stimuli. Given that the unexpected object and the task stimuli (either words or pictures) were perceptually unrelated, this also suggests that it is the semantic content of the stimuli which determines such findings rather than perceptual features. This paradigm thus seems particularly suitable for exploring the semantic variables involved in attention and IB. However, what remains unknown from this study is how
the attentional set balances ‘lower-level’ information such as shape, with ‘higher-level’ semantic expectations.

We also do not know whether featural characteristics are incorporated in the semantic attentional set to aid detection and recognition. Most et al. (2001) found that when participants were tasked with tracking four moving black or four moving white items, they would not see an unexpected white item if they were tracking the black items, and vice versa. However, when the unexpected object was grey, an intermediary of black and white, noticing percentages were similarly intermediate. This suggested that the more similar an unexpected object was to a target’s features, the more likely it was to be noticed. These findings thus raise the question of whether the semantic attentional set includes information about lower-level category features, or higher-level information only about category-exemplars and congruent concepts.

In a recent study by Tompkins (2012), using the IB paradigm designed by Koivisto and Revonsuo (2007), several surprising findings were uncovered relating to the semantic properties of two opposing categories: vehicles and fruit. Participants generally detected critical stimuli relating to categorically-congruent exemplar words, such as TRUCK when attending to vehicles, or GRAPES when attending to fruit, but not when attending to the incongruent category, consistent with previous findings. However, Tompkins also explored whether words that were categorically-congruent with the primary task in relation to item function would be detected in the IB paradigm. Here, whereas participants did seem to detect the verb RIDE when attending to vehicles, they did not detect the verb DRIVE, contrary to the expectation that the word DRIVE would have a strong semantic relation to the vehicles category.

Tompkins (2012) interpreted his findings as consistent with the hypothesis that detected words display semantic congruence with the attended category. He
suggested that RIDE captured attention due to its functional association with the
category of vehicles, citing evidence from priming effects in language between items
and other lexical entries corresponding to their functional utility (e.g., Hutchinson,
2003), as well as organisation of categories in terms of object use as well as properties
(Rosch & Mervis, 1975).

A further finding of interest from Tompkins (2012) was that during the
primary task where participants had to name presented pictures from one category,
many participants (>40%) failed to report the boat picture, despite near-perfect
accuracy reporting all other vehicle pictures in the primary task. This is attractive to
our research question of what category features and semantic properties determine the
attentional set, and to the question of what specific information is used to allow or to
deny stimuli into the attentional focus. For example, is the semantic knowledge,
which is activated for a specific category set to perceive perceptual, featural aspects
of a category member that distinguish it from other categories (i.e., a mouth in the
category of faces, or the colour green in the category of plants), or is it set to perceive
higher-level features, such as the relation of a category member to its action (i.e., the
action potential of a tool, or the manoeuvrability of a vehicle)?

We therefore decided to explore featural components of the attentional set,
using the Koivisto and Revonsuo (2007) paradigm. First, wheels are a key feature that
characterises vehicles, but were absent on the boat picture that Tompkins (2012)
found to be frequently missed in the primary task. It is possible that participants set
attention for ‘wheels’ when looking for primary-task vehicles. Therefore, we wanted
to test whether the unexpected word stimulus WHEELS would act similarly to a
category exemplar in terms of semantic congruence to the attended category, thus
demonstrating a low rate of IB. We hypothesised that participants would not detect
this word at a level similar to that of a category exemplar, if the featural property was used as a key determinant of the vehicle category in the perceptual but not the semantic attentional set. This condition would also allow us to independently gather data relating to the incidence of detection of the boat stimulus during the primary task. Second, we investigated the incidence of IB for WHEELS while participants attended to fruits, which we expected would yield higher rates of IB due to its semantic incongruence with the fruits category. Lastly, we wanted to test whether the word BOAT would yield high rates of IB, unlike category exemplars, given its previous lack of detection in the primary task of Tompkins (2012). If BOAT was detected like a category exemplar, this would suggest that the semantic attentional set for vehicles is specifically limited for exemplars, as well as there being a dissociation between the processing of primary-task pictures and unexpected word stimuli, at a semantic level.
Method

Participants

Sixty-five participants were recruited, all of whom were neurologically healthy, with normal or normal-to-corrected vision, and English as their native language. Each participant was reimbursed for travel and time with £5. Five participants were removed from the final analysis because they did not meet the inclusion criteria of speaking English as a native language, or were outside of our preferred age range (18 to 40 years). The remaining 60 participants (mean age = 22.8 years, range = 18 to 39; 32 females, 28 males) were randomly allocated to one of three experimental conditions. The protocol for testing approved by the University Research Ethics Committee was followed.

Apparatus

A CRT monitor, size 32.3 cm x 24.1 cm, was used to run the experiment, operating at a refresh rate of 60 Hz and a spatial resolution of 1024 x 768 pixels. Participants were seated, and a forehead and chin rest were used to fix the viewing distance between the participant and the monitor at 50 cm. The experiment was programmed and presented using E-Prime, version 2, Psychology Software Tool Inc., USA.

Stimuli

For the primary-task stimuli, pictures of vehicles and fruit were selected from the normalised line drawings of Snodgrass and Vanderwart (1980). Two additional images were included in the vehicle category, modified using Inkscape to match the visual complexity of the Snodgrass images. The positioning of each stimulus on the screen was matched to the original display size presented by Koivisto and Revonsuo.
Each vehicle or fruit picture (2.7° x 2.7°) was presented simultaneously at four locations flanking the fixation cross. The critical, unexpected stimuli were words, presented at fixation in size 28 Arial font, with all letters capitalised at a height of 0.7°.

For each condition, there were either three vehicles presented in the first and fourth trial, and one vehicle in the second and third trial, (3,1,1,3), or the pattern was the reverse (1,3,3,1; see Table 1). These conditions were counterbalanced amongst participants, and trials 5, 6, and 7 always presented two picture stimuli from each category. When the critical stimulus BOAT was used, one of the four pictures in trial 2 was of a tractor. When the critical stimulus WHEELS was used, one of the four pictures in trial 2 was of a boat, to ensure that the incidence of IB could not be confounded by priming effects elicited during the primary task.
Table 1

*Picture Stimuli Used in the Primary Task for Each Trial Pattern*

<table>
<thead>
<tr>
<th>Trial number</th>
<th>Pattern 1,3,3,1</th>
<th>Pattern 3,1,1,3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vehicles</td>
<td>Fruits</td>
</tr>
<tr>
<td>1</td>
<td>Wagon</td>
<td>Banana</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pineapple</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
</tr>
<tr>
<td>2</td>
<td>Motorcycle</td>
<td>Apple</td>
</tr>
<tr>
<td></td>
<td>Boat/Tractor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Truck</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Train</td>
<td>Tomato</td>
</tr>
<tr>
<td></td>
<td>Helicopter</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Car</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Airplane</td>
<td>Cherry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Watermelon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peach</td>
</tr>
<tr>
<td></td>
<td>Bicycle</td>
<td>Pear</td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>Strawberry</td>
</tr>
</tbody>
</table>

*Procedure*

Participants were seated at a computer monitor. The experimenter read standardised instructions, which differed only according to the object category being attended to: either vehicles or fruits. Participants were then able to familiarise themselves with the procedure of the trials, using a paper analogue presented to them by the experimenter and based upon the standard four-picture array using items from the vehicle and fruit categories. The participant was presented a blank page, followed by a fixation cross centred within the white circle, a page depicting the stimulus slide containing two vehicles and two fruit, followed by another blank page at which the
participant was asked to report the items belonging to the attended category. The experimental trials did not re-use any of the images of fruit or vehicles used during the practice trial.

In the experiment proper, seven trials were presented (see Figure 1), each of which began with a fixation cross presented for 1s in the centre of a round, white viewing area, superimposed upon a black background. Four pictures of vehicles and fruit appeared, which remained on screen for a 1200ms duration. A blank screen then prompted participants to verbally report the names of the pictures belonging to the category to which they were attending. To initiate the next trial, participants were prompted by the experimenter to press the spacebar. The first four, non-critical, trials each contained a four-picture array surrounding the fixation cross. Trial five was the first trial to include an appearance of the unexpected, critical word stimulus. This trial was therefore of primary research interest, and known as the critical trial. Condition 1 contained the critical stimulus BOAT and all participants were asked to attend vehicles. The critical trial for conditions 2 and 3 both contained the critical stimulus WHEELS, with two sets of task instructions, either to attend vehicles or to attend fruits (see Table 2).
Figure 1. Example of trial procedure for both a non-critical trial (left), and for a critical trial (right) where the unexpected word stimulus appeared centrally at fixation.

Trials 1-4 were all non-critical, and trials 5-7 presented the central word stimulus.

Table 2

<table>
<thead>
<tr>
<th>Condition</th>
<th>Attend</th>
<th>Ignore</th>
<th>Critical Stimulus</th>
<th>No. of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vehicles</td>
<td>Fruits</td>
<td>BOAT</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Vehicles</td>
<td>Fruits</td>
<td>WHEELS</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Fruits</td>
<td>Vehicles</td>
<td>WHEELS</td>
<td>20</td>
</tr>
</tbody>
</table>

Following the critical trial and reporting of the attended pictures, the experimenter asked the participant whether they had seen anything additional on the last trial ("There were 4 pictures on the last trial. Did you see anything other than the four pictures?") The participant’s verbal response was recorded and they were asked
to describe the exact details of what they had seen and where it was located. If a participant reported the critical stimulus, with either correct identity or correct location, they were classified as *noticers*. Those who did not report the critical stimulus were classified as being inattentionally blind on the critical trial. All participants were then asked whether they were able to report the images of the category items they had been instructed to ignore on the critical trial.

Trial 6 was referred to as the *divided-attention trial*, as all participants had now been alerted to the possibility of stimuli other than the four expected pictures. Thus in this trial the participants were thought to divide attention between doing the primary task and looking for something additional.

Trial 7 was referred to as the *full-attention trial*, which again was identical to the critical and divided-attention trials except for different pre-trial instructions. Participants were not asked to report pictures from either category. Instead they were told, *“This is your final trial, and your instructions are slightly different. Rather than reporting vehicles (fruits), just look for any additional items appearing on the screen. You do not need to report the vehicles (fruits) at the end of this trial. Ready?”* The purpose of this trial was to verify that the participant was able to detect the critical word stimulus when their attention was not engaged by a primary task of picture naming.

Finally, participants were asked questions relating to their knowledge of IB, and whether they were familiar with any specific research, to ensure that any findings could not be related to participant expectations about unexpected stimuli being included in the experiment.
Results

All statistical analyses were conducted using SPSS v21.0.0 for MAC, and all results evaluated using an alpha level of .05. Primary-task accuracy was assessed using Mann-Whitney U Tests. The effect of pattern in the primary task, and the incidence of IB for each condition was analysed using two-tailed Chi-Square Tests. For Chi-Square Tests, assumptions were met for raw frequency data, random sampling and independence of observations. Chi-Square analyses were based on a 2x2 contingency table, so the Yates Continuity Correction value was reported. The effect size reported was the Φ coefficient, with effect sizes judged according to Cohen’s (1988) criteria.

Primary-task Accuracy

To confirm that noticers and non-noticers displayed equivalent attentional and/or motivational investment in the task, we analysed the primary-task accuracy for the reporting of items in the attended category (vehicles or fruits). There were eight items in each primary task (trials 1–4), and we expected high levels of accuracy if all participants were motivated and attending to the task. Across all three conditions, a Mann-Whitney U test revealed no significant difference in primary-task accuracy among noticers (Md = 8.0, n = 32) and non-noticers (Md = 7.0, n = 28), U = 388.0, z = -0.959, p = .337, r = -0.12 (small effect).

When participants attended to Vehicles, with the critical stimulus WHEELS, we were able to collect data for the proportion of participants who noticed and reported the boat stimulus in the primary task. Twelve participants out of 20 failed to report the boat stimulus (60%), consistent with the previous findings of Tompkins (2012).
The Incidence of Inattentional Blindness

Our key analysis was for the incidence of IB in each condition on the critical trial and divided-attention trial (see Figure 2): WHEELS (attend Vehicles/Fruits) and BOAT (attend Vehicles). Our analyses aimed to explore whether the semantic attentional set is sensitive to high-frequency featural aspects of the category, given the previous findings of Tompkins (2012) that a significant proportion of participants did not classify a sail boat as a vehicle in the primary task.

Is WHEELS included in the semantic attentional set for Vehicles?

The first analysis investigated whether a category-congruent featural concept (WHEELS) would be detected with comparable frequency to an anticipated category exemplar (BOAT). Given that our unexpected stimulus was in word format, any attentional capture on critical or divided-attention trials must be due to semantic association with the category of Vehicles.

A Chi-Square Test for the critical trial indicated that IB rates did not differ significantly for the unexpected stimulus WHEELS when attending Vehicles (IB = 45%), compared to BOAT when attending Vehicles (IB = 30%), $\chi^2(1, N = 40) = .427$, $p = .514$, $phi = .155$ (small effect). For the divided-attention trial, IB rates also did not differ significantly for WHEELS when attending Vehicles (IB = 35%), compared to BOAT when attending Vehicles (IB = 20%), $\chi^2(1, N = 40) = .502$, $p = .288$, $phi = .168$ (small effect).

Is WHEELS a category-congruent feature?

We then investigated whether the critical stimulus WHEELS was detected more frequently when individuals were searching for vehicles (category-congruent) rather than for fruits.
A Chi-Square Test for the critical trial indicated that IB rates did not differ significantly for WHEELS when attending Vehicles (IB = 45%), compared to WHEELS when attending Fruits (IB = 65%), $\chi^2(1, N = 40) = .909, p = .340, \phi = -.201$ (medium effect). For the divided-attention trial, IB rates also did not differ significantly for WHEELS when attending Vehicles (IB = 35%), compared to WHEELS when attending Fruits (IB = 60%), $\chi^2(1, N = 40) = 1.604, p = .205, \phi = -.250$ (medium effect).

**How do our stimuli compare to a strong category exemplar?**

The data from two conditions was then compared with the findings of Tompkins (2012) to further explore how WHEELS and BOAT compare to previously stimuli tested using the same paradigm and procedures for data collection. We compared our conditions of interest to a confirmed category exemplar, TRUCK, which Tompkins found to be resistant to IB (IB = 11.8%). It is possible that BOAT is simply a weaker category exemplar than TRUCK, not allowing us to accurately assess whether WHEELS is also treated similarly to a category exemplar.

On the critical trial, rates of IB did not differ significantly for the unexpected stimulus TRUCK when attending Vehicles (IB = 11.8%) compared to WHEELS when attending Vehicles (IB = 45%), $\chi^2(1, N = 37) = 3.398, p = .065, \phi = -.362$ (large effect). Likewise, there was no difference in rates of IB for TRUCK (IB = 11.8%), and WHEELS when attending Vehicles (IB = 35%) on the divided-attention trial, $\chi^2(1, N = 37) = 1.581, p = .209, \phi = -.270$ (medium effect).

On the critical trial, rates of IB also did not differ significantly for the unexpected stimulus TRUCK when attending Vehicles (IB = 11.8%), compared to the unexpected stimulus BOAT when attending Vehicles (IB = 30%), $\chi^2(1, N = 37) = .888, p = .346, \phi = .221$ (medium effect). Again, there was no difference in rates of
IB for TRUCK (IB = 11.8%) and BOAT, attend Vehicles (IB = 20%) on the divided-attention trial, \( \chi^2(1, N = 37) = .053, p = .818, phi = -.111 \) (small effect).

*Figure 2.* Rates of IB for each of the critical stimuli on the critical trial: WHEELS (attend Vehicles), BOAT (attend Vehicles), TRUCK and WHEELS (attend Fruits).
Discussion

Our study used the Koivisto and Revonsuo (2007) paradigm to explore how the attentional set for physical, featural characteristics interacts or coincides with the attentional set for semantic characteristics for the category of vehicles. Two distinct findings have emerged. First, the semantic featural property common to vehicles, WHEELS, demonstrated a different trend for the rate of IB compared to category exemplars such as TRUCK (45% versus 12% IB), and also did not appear to be a category-congruent feature on a semantic level (45% versus 65% IB for WHEELS, attend Vehicles versus WHEELS attend Fruits). Second, the failure of participants to report the picture of the boat in the primary task remains puzzling given their greater trend of success in reporting the unexpected word BOAT.

The importance of featural properties to the attentional set

Our results are consistent with our hypothesis that unexpected words relating to semantically-congruent features (WHEELS) would not be immune to IB, demonstrating their lack of importance to the semantic attentional set. Although non-significant when compared to TRUCK, the near-significance ($p = .065$) and small sample size leads us to argue that with more participants, significance would be likely. This finding colludes with the possibility that featural aspects of category stimuli are only relevant to the pre-attentive perceptual stages of identification. Recent work by Evans and Treisman (2005) may provide further insight into this possibility. Evans and Treisman found that visual feature overlap provided a pertinent distraction when participants were tasked with responding to a specific category and ignoring another category. They found that animals were more difficult to identify when interspersed with images of humans, than when the two categories shared fewer
features (vehicles versus humans). When replicated with words instead of pictures however, they found no difference in detection accuracy or latency for animals compared to humans, suggesting that such effects were more likely to be due to perceptual feature overlap than semantic interference, and that semantic feature overlap may not be distracting. This finding is consistent with our findings for WHEELS, as the semantic featural overlap did not affect our participants’ performance.

Evans and Treisman suggested that preattentive processing of category-congruent features occurs prior to attention being invoked and the experience of conscious detection of a stimulus, then facilitating detection and acting as a route to conscious perception. They propose that binding and individuation of high-level objects does not occur until the individual has correctly detected relevant disjunctive sets of features. The evidence thus suggests that simple detection could plausibly be mediated by features, at a processing stage prior to full binding and identification. It would be particularly interesting to invert our experiment so as to provide word stimuli in the primary task as the four stimuli, and an unexpected picture of wheels as the unexpected stimulus, to see whether in the absence of a need for visual categorisation and pictorial featural importance, the picture of wheels would be detected.

Future studies could aim to test whether participants report a different key feature if presented within the primary task as one of the four stimuli. For example, if we compared two categories, such as vehicles and animals, but swapped key features (for example, some vehicles may have legs while animals have wheels), this may also disrupt accuracy rates. Our findings still do not shed light on whether features constitute finite, categorical variables during initial processing (i.e., whether
participants exclude stimuli based upon categorical algorithms such as “does the object have wheels?” or whether more continuous featural variables are also considered. The findings of Most and colleagues (2001) suggested that participants were more likely to see grey unexpected items when tracking black shapes, than white unexpected items, suggestive of processing algorithms based upon similarity rather than an exclusion principle, although it could equally be argued that the ‘categories’ in Most et al.’s task were simple, with little relevant semantic information to decide between the two categories thus making perceptual information more salient.

Our findings provide evidence against the view first proposed by Mack and Rock (1998) that unexpected stimuli may undergo relatively advanced analysis prior to being selected for awareness. The difference between perceptual and conceptual levels of analysis is reminiscent of the mechanistic distinction suggested by Most (2010) between potentially separate forms of IB. The first type, ‘spatial IB’, is argued to arise from the covert misallocation of spatial attention, directing spatial attention to objects with relevant features and ignoring those without. Findings discussed previously with regards to the perceptual properties of the attentional set, including shape and colour, could be considered to fit within this definition. The second distinct type proposed by Most, ‘central IB’, may better reflect the semantic salience of unexpected word stimuli pertaining to category exemplars such as TRUCK or BOAT. Such a process may reflect the interface between perceptual mechanisms, such as feature detection for wheels in the primary-task pictures, and higher-level processes such as working memory and semantic knowledge, which would be positioned to detect semantic congruency for the word stimuli corresponding to category exemplars. Inverting our experiment so as to provide word stimuli in the primary task as the four stimuli, and an unexpected picture of wheels as the unexpected stimulus,
would allow us to see whether a task more reliant on ‘central’ processing would still prime a perceptual attentional set for the visual image of wheels.

**The Boat Paradox**

Our second finding of interest was a trend for a difference between the proportion of participants failing to notice the boat in the primary task (60%) and the proportion of participants with IB for the unexpected word stimulus BOAT (30%). Current perspectives on the attentional set hypothesis indicate that the attentional set should remain relatively stable during ongoing perception. Koivisto and Revonsuo (2007) previously argued that given the lack of perceptual relatedness of the primary-task stimuli and unexpected objects (words and pictures), semantic content and appraisal must therefore drive conscious detection. Consequently, our findings concerning the boat present a paradox for our understanding of the processes mediating IB: why would the attentional set allow the sail boat picture in the primary task to go unnoticed, while the semantics of the word BOAT seemed much more salient? This provides further evidence for a pre-attentive ‘spatial’, featural analysis, followed by ‘central’ semantic analysis.

Contrary to our hypothesis, IB for BOAT did not differ significantly from the rate of IB for confirmed category-exemplar TRUCK. This suggests that BOAT may also be considered a category exemplar during semantic analysis. Plausibly, report of the picture of the boat in the primary task may appear lower due to the immediate, perceptual features being ‘less typical’ of vehicles (i.e., no wheels) whereas semantically, the concept of a boat, presented as the unexpected word stimulus, may have been represented as more typical of the category.
The potential for category typicality effects is consistent with the important role of features, reflected by classical prototype theories of categorisation (Medin & Schaffer, 1978). One intriguing possibility is that the strength of the category-exemplar effect could be mediated by featural similarity between items, with the boat demonstrating less of a category-exemplar effect due to its fewer shared features with the vehicle category. It may be possible to test this by systematically manipulating the featural variables of a stimulus to correspond to several degrees of ‘vehicle-similarity’, which we would then expect to interact with the incidence of detection in such tasks. The degree of featural similarity may, as Evans and Treisman (2005) suggested, mediate the likelihood of the stimulus reaching awareness.

Components of the attentional set

Our findings complement previous results that have demonstrated that category exemplars such as TRUCK (Tompkins, 2012) show heightened immunity to IB, as do some (but crucially not all) action-related words (RIDE but not DRIVE; Tompkins, 2012). One question arising from these results alongside those of Tompkins (2012) is why semantic immunity to IB seems to only affect category exemplars? Rather than the attentional set being widely attuned to all relevant semantic properties of a certain category, it could be argued that the semantic attentional set is fairly narrow, as suggested by Aimola Davies, Mansell, Forkert and White (in preparation) who found a category exemplar effect for animals versus fruit, but not for the words ZOO or FARM. A particularly narrow semantic attentional set may therefore be tuned to very task-specific information based upon the goal to distinguish stimuli from opposing categories.
The category-exemplar effect could instead reflect a secondary component of the paradigm, concerning the response modality necessitated by the task. When scrutinised, the task includes two specific components that may differentially affect the participant’s attentional set. First, the participant must identify the members of the four stimuli that correspond to the attended category. However, the second aspect of the task requires participants to verbally recall the name of the presented members of their attended category. Therefore, the individual must re-tune their internal attentional set from items of perceptual and semantic congruency to search for the appropriate lexical entries to report.

The attentional set theory does not explicitly specify how such a change in task demands may affect its content. When identifying the category-item/s, the participant may have pre-activated information relating to a category’s prototypical features (i.e., vehicles may typically have wheels). The corresponding lexical item for the subsequent naming task would require pre-activation of lexical entries relating to common category exemplars that may need to be named. This may theoretically include syntactic constraints upon lexical access, such as a pre-activation of all nouns with appropriate semantic associations.

As an individual would not expect to see an item corresponding to a verb (i.e., you don’t typically name an object “accelerate”), such items, although semantically-congruent, may be inhibited or less likely to reach an activation threshold, consistent with Tompkins’ (2012) finding relating to the unexpected stimulus DRIVE. The reason that the majority of people see RIDE in Tompkins’ study may reflect the fact that “ride” can be used as a noun (“the man took a ride at the circus”). This would imply that the findings related to which words go unnoticed might relate to lexical competitors rather than the semantic components of an attentional set. Similarly for
WHEELS, participants would not expect to name a feature rather than a whole, bound object. When moving between identification and naming tasks, therefore, the individual’s attentional set might have to balance the constraints upon lexical, semantic, and perceptual variables. It may be more fitting to separate the processes into separable “attentional sets”, firstly to guide attention to external task-relevant details based upon semantic memory and visual processing, and an-output driven “lexical access attentional set” directed internally to stored lexical representations.

**Summary and future directions**

To summarise, our results demonstrate that features may provide a key determinant of the contents that reach our attention, mediating what is noticed and what is prone to IB, but do not show semantic immunity to IB. Given this, it appears that the attentional set theory must acknowledge the importance of Most et al.’s (2001) conception of the “feature-based attentional set” alongside the possibility of componential attentional sets relating to task demands (such as the possibility of an internal “lexical attentional set”). Whether feature-based attentional sets act in a categorical way, or are determined by similarity, is an important question for future research to address, as is the question of which key features do characterise the attentional sets for individual categories. Despite rocking the boat, our findings add to our growing knowledge of how the attentional set may be comprised of different components, and the way in which these components may interact and act to bias ongoing visual processing.
References

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