
Journal of Cognitive Psychology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pecp21

# Dissociation between visual attention and visual mental imagery

William L. Thompson [a] , Yaling Hsiao [b] & Stephen M. Kosslyn [a c]
[a] Department of Psychology, Harvard University, Cambridge, MA, USA
[b] Department of Psychology, University of Wisconsin-Madison, Madison, WI, USA
[c] Department of Neurology, Massachusetts General Hospital, Boston, MA, USA

Available online: 16 Feb 2011

To cite this article: William L. Thompson, Yaling Hsiao & Stephen M. Kosslyn (2011): Dissociation between visual attention and visual mental imagery, Journal of Cognitive Psychology, 23:2, 256-263

To link to this article: http://dx.doi.org/10.1080/20445911.2011.477810

JOURNAL OF COGNITIVE PSYCHOLOGY, 2011, 23 (2), 256–263

Psychology Press
Taylor & Francis Group

# Dissociation between visual attention and visual mental imagery

**William L. Thompson[1], Yaling Hsiao[2], and Stephen M. Kosslyn[1,3]**

[1]Department of Psychology, Harvard University, Cambridge, MA, USA
[2]Department of Psychology, University of Wisconsin-Madison, Madison, WI, USA
[3]Department of Neurology, Massachusetts General Hospital, Boston, MA, USA



Visual mental imagery (which involves creating, interpreting, and transforming visual mental representations, i.e., ‘‘seeing with the mind's eye'') and visual attention typically are described as distinct processes. However, some researchers have claimed that imagery effects can be explained by appeal to attention (and thus, that imagery is nothing more than a form of attention). In this study, we used a size manipulation to demonstrate that imagery and attention are distinct processes. We reasoned that if participants are asked to perform each function (imagery and attention) using stimuli of two different sizes (large and small), and that stimulus size affects the two functions differently, then we could conclude that imagery and attention are distinct cognitive processes. Our analyses showed that participants performed the imagery task better when stimuli were large, whereas they performed the attention task better when stimuli were small. This finding demonstrates that imagery and attention are distinct cognitive processes.

***Keywords:*** Mental imagery; Visual attention; Dissociation; Visual mental representations; Image size.

Visual mental imagery involves creating, interpreting, and transforming visual internal representations (‘‘seeing with the mind's eye''), whereas attention involves selecting some information for more detailed processing (while discarding other information). At first glance, the two functions appear distinct. Nevertheless, some researchers have claimed that mental imagery effects do not reflect characteristics of a distinct form of internal representation, but rather are best understood as products of attention. Pylyshyn (e.g., 1989, 2002, 2003), for example, has proposed that results from many ‘‘imagery'' experiments actually reflect the allocation of attention to different portions of the space that would be occupied by an image. Pylyshyn (2002, p. 158) states that ‘‘the use of visual indexes and focal attention provides a satisfactory explanation for how spatial properties are inherited from the observed scene, without any need to posit spatial properties of images''. For example, when visualising a house on a blank wall, the participants may think ‘‘the front door would be where the speck on the wall is'', with attention being allocated to different regions of space as the image is constructed descriptively.

Similarly, Pani (2002) has echoed Pylyshyn's view that phenomena attributed to mental imagery (such as the visualisation of letters within a $4 \times 5$ cell grid) are actually due to the allocation

Correspondence should be addressed to William L. Thompson, Harvard University, Department of Psychology, 844 William James Hall, 33 Kirkland Street, Cambridge, MA 02138, USA. E-mail: wt@wjh.harvard.edu

This research was supported by Grant No. R01 MH060734 from the National Institute of Mental Health. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Institute of Mental Health.


http://www.psypress.com/ecp DOI: 10.1080/20445911.2011.477810

of attention to defined regions of space. This idea gains credence because Craver-Lemley and Reeves (1992) have shown that imagery and attention can interact in some circumstances: in particular, the Perky effect (i.e., the interference with visual perception that is produced by a mental image occupying the same space as a foveal visual percept) when attention is divided is half of that observed when attention is focused. If the Perky effect is taken as evidence that imagery and perception rely partly on the same neural systems, then the fact that divided attention decreases the effect whereas focused attention increases it could suggest that imagery effects arise, at least in part, from focused visual attention. We should note, however, that this effect of attention on imagery/perception interference only occurs when the perceptual targets are in the periphery of the visual field.

There is also evidence that both visual imagery (e.g., Kosslyn & Thompson, 2003; Kosslyn, Thompson, & Ganis, 2006) and visual attention (e.g., Silver, Ress, & Heeger, 2005) can lead to increased activity in early visual cortex, and attention may enhance performance of tasks that rely on this neural structure (e.g., Hopfinger & West, 2006). These results make it difficult to disentangle effects due to imagery versus attention (but, see Offen, Schluppeck, & Heeger, 2009, for evidence that attention and visual short-term memory rely on different processes in early visual cortex). In addition, Grossberg (2000) has suggested that a combination of mismatched attentional and top-down expectancy effects can give rise to the experience of perceiving a stimulus in its absence in the case of schizophrenic hallucinations.

However, Ishai, Haxby, and Ungerleider (2002) conducted a neuroimaging study in which they explicitly examined the effects of attention on imagery processing. They asked participants to visualise famous faces and, in one condition, asked them to focus their attention on a particular feature of the face (such as nose or lips). They found that requiring attention during imagery increased activation in only a subset of areas activated by imagery (in some frontal and parietal regions), which suggests that the two processes are different.

If attention and imagery rely on distinct mental processes, then some variables should affect imagery and attention differently. Specifically, the size of the stimulus used in an attention or an imagery task may be one such variable. In fact, for attention, there is evidence that people have more difficulty detecting faint visual signals if their attention is distributed over a large area than a small one (Eriksen & St. James, 1986); conversely, for imagery, people have more difficulty detecting parts of a visualised object if the image is small than if the image is large (e.g., Kosslyn, 1975). Along the same lines, they also have poorer memory for objects visualised at small sizes versus large sizes (Kosslyn & Alper, 1977). In the present study, we compare directly the effects of size in attention versus visual mental imagery, using matched paradigms with the same participants.

If imagery and attention rely on the same processes, then manipulating the size of objects to be attended to or to be visualised should have the same effect. If, on the other hand, varying the size of the stimuli produces different results for imagery and attention, then the two functions cannot rely on identical sorts of processing—and we are justified in concluding that imagery cannot be reduced to attention.

## METHOD

### Participants

The participants were 38 volunteers (17 females and 21 males) recruited from the Harvard University Department of Psychology Study Pool website. Six participants were excluded from the study because they failed to understand the instructions in at least one task. Data from the 32 participants (16 females and 16 males) who successfully performed all tasks were retained for further analysis. The majority of the participants were Harvard undergraduate students or local residents, with a mean age of 23.5 years (range: 18–35 years). The study was approved by the Harvard University Faculty of Arts and Sciences Committee on the use of Human Subjects and participants were tested according to all applicable guidelines and regulations governing research with human participants.

### Materials

Test stimuli were programmed into the PsyScope display program (Cohen, MacWhinney, Flatt, & Provost, 1993) and were presented on the 15-inch screen of a Macintosh computer. Two conditions were administered to each participant: attention and imagery. In the attention condition, participants were asked to focus on a square at the centre of the screen. The square was either large, 16.5 × 16.5 cm, or small, 1.8 × 1.8 cm. Once participants had focused their attention on the square, on half the trials a small dot, approximately 1 mm × 1 mm, appeared somewhere within the boundaries of the square. Participants were asked to indicate, by pressing a key on the computer keyboard, when they detected the dot. The squares had white interiors surrounded by a black frame. For each square, eight positions were defined where the dot might appear, and all were two-thirds of the distance from the centre to the edge of the square and of equal distance to each other. Figure 1 illustrates all the possible positions of the dots. The 48 trials were divided into two blocks of 24 trials. Each block consisted of a series of 24 trials that were to be performed at either a large or small size (using the appropriately sized square to set the area of attention or the size of the object to be visualised).

The design of the imagery condition was identical to that of the attention condition, except that, after the dot detection portion of the task, participants were asked to make an additional judgement about whether a common object or animal possessed a particular feature. Thus, two sound files were presented on each imagery trial: the first was the name of the object (to cue participants to visualise it) and the second was the characteristic (on which participants judged the object they had visualised). For the imagery condition, we selected 48 common objects or animals from a larger set of approximately 100 common objects or animals. The investigators produced a list of common objects and, for each object, a property that the authors used imagery to verify (for example, ‘‘elephant’’–‘‘hanging ears’’). These objects and their properties were pilot tested with a group of 26 college-age participants and we retained only those combinations where at least two-thirds of the participants provided the correct response. The questions were created so that half were true (i.e., the property was in fact a characteristic of the object) and half were false. The objects and accompanying properties were then divided into two groups of equal difficulty to be counterbalanced across size conditions of the study. See Table 1 for a list of the items included in the study.

## Procedure

Participants were tested individually in a small room with the lights on, and were seated at approximately 60 cm from the computer screen.

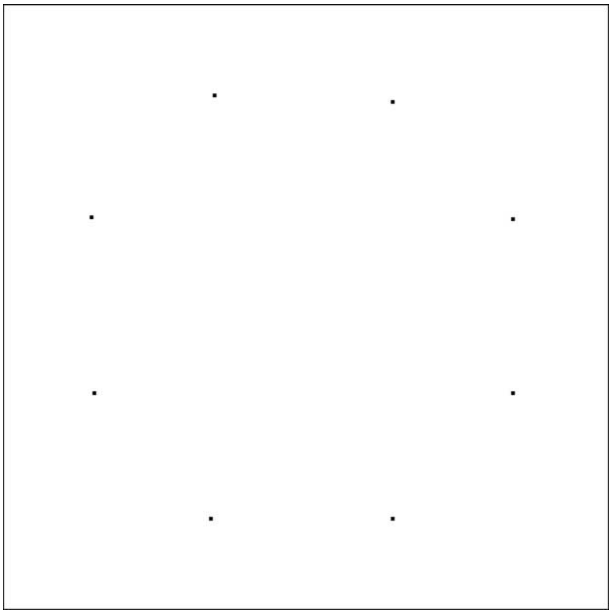

**Figure 1.** A model of the type of square used in the attention and imagery conditions with dots at all 8 possible locations. The small square measured 1.8 cm × 1.8 cm and the large square measured 16.5 cm × 16.5 cm. Both sizea of square were used in the imagery and attention conditions. The dots, which measured approximately 1 mm × 1 mm, remained at the same size regardless of wheather the square was presented at a large or small size.

**TABLE 1**
Imagery items and properties, divided into "true" and "false" groups

| *True* | | *False* | |
|---|---|---|---|
| *Item* | *Property* | *Item* | *Property* |
| Elephant | hanging ears | Pig | round ears |
| American flag | blue stars | Donkey | hanging ears |
| Cube | 8 corners | Mercedes symbol | 3 curved lines |
| Star of David | 6 points | Parking meter | flat top |
| Cell phone keypad | 0 at bottom | Washington Monument | dome |
| Tic-tac-toe game | 4 lines | Statue of Liberty | torch in left hand |
| Kayak | two pointed ends | Elvis Presley | mustache |
| Stop sign | 8 sides | Chicken | webbed feet |
| Bald eagle | hooked beak | Nike symbol | higher than wide |
| Horse | pointy ears | George Washington | beard |
| Panda | black ears | Ace of clubs | 4 leaves |
| Sea lion | flippers | Kangaroo | short tail |
| Maple leaf | jagged edge | Honeycomb | 5 sides |
| Penguin | white belly | Apple logo | bitten left side |
| Olympic symbol | 5 rings | Star fish | 6 points |
| Superman logo | red letter S | Egyptian pyramid | triangular bottom |
| Mickey Mouse | gloves | Fire hydrant | square shape |
| Charlie Chaplin | mustache | Recycling symbol | counterclockwise arrows |
| Traffic light | red on top | American passport | wider than high |
| Eiffel Tower | 4 legs | Starbucks symbol | triangular shape |
| Face of 1-dollar bill | George Washington | Albert Einstein | glasses |
| Pepsi symbol | red on top | Sphinx | standing |
| American flag | red stripe on top | Cookie Monster | green fur |
| Ronald McDonald | striped socks | Winnie the Pooh | red nose |

Each received both the attention and imagery conditions, with the order counterbalanced over participants. A test session lasted approximately 60 min, about half of which was devoted to the computer-administered tasks and the rest to a set of written questionnaires. Each condition consisted of two blocks of trials, one where participants attended to (in the attention condition) or visualised within (in the imagery condition) an area defined by the large square and one block where they attended to or visualised within an area defined by the small square. Half of the participants began with the block of "large" trials; the other half began with the "small" trials. Each block started with detailed instructions and four practice trials to familiarise the participant with the task.

## Attention condition

Participants were asked to pay attention to an empty square (either large or small, depending on the block of trials) on the computer screen. They were asked to focus their attention on the square, and when they were ready (they were allowed as much time as they felt was needed to focus their attention fully) they pressed the spacebar. Once the spacebar was pressed, there was a delay, following which, on half the trials, a black dot would appear for 20 ms. The exact timing of the dot's appearance was varied from trial to trial so that participants could not predict the specific time when the dot might appear, which required them to remain vigilant. Specifically, the delay (after the spacebar was pressed) was either 1.5, 2.0, or 2.5 s, and this timing was counterbalanced across trials, where no more than two consecutive trials with dots had the same delay duration, and every duration occurred approximately an equal number of times in the first and the second half of a 24-trials block.

Participants were instructed to respond as quickly and accurately as possible by pressing the "yes" key ("yes" and "no" labels were affixed to the "b" and "n" keys, respectively) on the keyboard as soon as they saw the dot. When a dot did not appear, the empty square persisted for 4 s and another trial ensued. There was a 250 ms interval between trials. On trials where a dot did not appear, participants were instructed simply not to respond. If the participants mistakenly thought that they had seen a dot (which in fact did not appear) and responded with the "yes" key within 4 s, the trial would be terminated and followed by the next trial after a 250 ms interval. If the ''yes'' key was not pressed within 4 s, the participant's response would be considered ''no dot''. The end of each trial was signalled by a beep. No more than three trials of the same type could occur in a row. On trials where a dot did appear, the location of the dot was counterbalanced within a block of trials. In addition, the same dot position never appeared in consecutive trials, and could only appear once or twice in each the first set of 12 and the second set of 12 trials of the block.

## Imagery condition

A judgement task based on the properties of the visualised objects was incorporated into the imagery condition in addition to the dot detection task. Participants were presented with an empty square at the beginning of each trial, either large or small depending on the block. After 1 s, a word sound file named an object (e.g., ''elephant''), which the participants were asked to visualise. They were instructed to create a vivid image that filled the square without overflowing it, and to project that image onto the screen. The participants were to press the spacebar when a clear and vivid image had been completely generated. As in the attention condition, after 1.5, 2.0, or 2.5 s, a dot could appear briefly for 20 ms (the dot appeared on half of the trials). Participants were to press the ''yes'' key if they detected a dot or to wait 4 s without responding if they did not see a dot. The dot detection task ended once the ''yes'' key was pressed or after 4 s had passed without a response, with both situations being signalled by a beep. The participants were to maintain the vivid mental image of the cued object at all times while performing the dot detection task. After a 1 s delay, the participants heard a second word or phrase describing a part or property that may or may not characterise the object that they were visualising (e.g., ''hanging ears''). Participants were instructed to decide whether the named object had the characteristic by inspecting the mental image they had projected into the square. They indicated their decisions by pressing the ''yes'' or ''no'' key on the keyboard. Half of the trials required a ''yes'' response and the other half required a ''no'' response. The correct answers were never the same more for than three trials in a row. There were six questions with ''yes'' as the correct response and six with ''no'' as the correct response in each set of 12 trials within a block. No time limit was imposed on the task. A beep sound indicated that the response had been recorded, and a new trial began 250 ms after each response.

The objects used in the imagery task were pilot tested and divided into two groups that were equated for difficulty. The two sets of objects were counterbalanced over order and size of the image to avoid potential confounds.

## Questionnaires

Following the computer-administered tasks, we asked the participants to complete a series of questionnaires on mental imagery, a handedness questionnaire, and a personal health history to assess their vision and hearing.

# RESULTS

We analysed the time to detect the dots in both the attention and imagery conditions and the time to evaluate the properties in the imagery task. We first discarded response times (RTs) of incorrect responses and those that were more than 2.5 standard deviations greater or smaller than the cell mean for that participant. Approximately 1% of the trials were excluded overall. The error rates for dot detection included trials where the participant missed the dot (misses) and where he or she incorrectly responded ''yes'' in the trials without a dot (false alarms). We also analysed the time spent on focusing attention on the square for dot detection in the attention condition and that on generating the mental image of the named object in the square in the imagery condition. Finally, we calculated $d'$ and beta for each participant for the dot detection task in both the attention and imagery conditions.

## Size effects in attention versus imagery

We began by examining the data most relevant for our hypothesis. We conducted a 2 (imagery judgement vs. dot detection in the attention condition) $\times$ 2 (task performed at large vs. small size) ANOVA for both response times (RT) and error rates (ER).

*RT analysis.* Participants required less time in the dot detection task in the attention condition (398 ms) than they did to make judgements about objects they had visualised in the imagery condition (1139 ms), $F(1, 31) = 75.95$, $MSE = 230844$, $p < .0001$. No other main effects or interactions were significant.

*ER analysis.* Participants made fewer errors in detecting dots in the attention task when the size of the square was small (0.9%) than when it was large (6.3%), whereas in the imagery task (in which they judged characteristics of objects) they made fewer errors when the size of the square into which the image was projected was large (15.4%), than when it was small (20.4%), $F(1, 31) = 37.3$, $MSE = 0.002$, $p < .0001$. Post hoc contrasts revealed that the differences between each size pair (large and small) were significant in both the attention, $F(1, 31) = 19.77$, $MSE = 0.002$, $p < .0001$, and the imagery, $F(1, 31) = 17.56$, $MSE = 0.002$, $p < .0002$, tasks. See Figure 2 for an illustration of these results.

In addition to the interaction, we also found that participants made fewer errors in the attention condition overall (3.6%) than in the imagery judgement condition overall (17.9%), $F(1, 31) = 106.55$, $MSE = 0.006$, $p < .0001$.

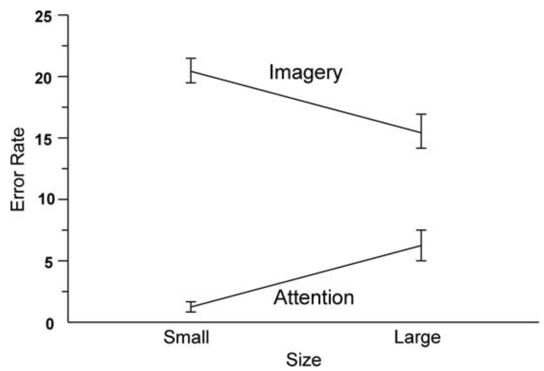


**Figure 2.** Errors in attention and imagery conditions performed at large and small sizes.

## Dot detection in imagery versus attention

Because smaller images are denser in their features and because visual images can interfere with like-modality perception (the so-called Perky effect; e.g., Craver-Lemley & Reeves, 1992), we conjectured that the dot detection effect (facilitation when attending to a small region of space) might be attenuated during the small-size imagery condition. Thus, using a $2 \times 2$ ANOVA, we compared dot detection in the imagery and attention conditions, at the large and small size.

*RT analysis.* Participants required more time to detect the dot during the imagery condition (532 ms) than during the attention condition (398 ms), $F(1, 31) = 92.3$, $MSE = 6229$, $p < .0001$. Participants required more time overall to detect the dot when the square was large (487 ms) than when the square was small (444 ms), $F(1, 31) = 27.6$, $MSE = 27.62$, $p < .0001$. The interaction between the two factors was not significant, $F(1, 31) = 0.48$, $MSE = 2311$.

*ER analysis.* Participants made more errors in dot detection when the square was large (6.5%) than when it was small (1.7%), $F(1, 31) = 16.46$, $MSE = 0.005$, $p = .0003$. No other main effects or interactions were significant.

We found no effects of image generation time, nor of time to focus attention.

## Signal detection analysis

Signal detection analyses allow us to consider both the participant's sensitivity to a given target ($d'$) as well as any response biases (beta) for "yes" or "no" responses when signalling that they have or have not detected the target.

*Size effects in attention and imagery dot detection.* We began with a $2 \times 2$ ANOVA comparing dot detection in the two conditions (attention and imagery) and at the two sizes (large and small). We conducted separate analyses for $d'$ and beta as the independent variables. For $d'$, the analysis revealed only that the participants had greater sensitivity to the dot when the square was small (mean = 3.3) rather than large (mean = 2.9), $F(1, 31) = 17.78$, $MSE = 0.225$, $p = .0002$. No other main effect or interaction was significant. The same analysis for beta revealed a higher value (a greater bias towards "no" responses) in the imagery condition (mean = 0.18) than in the attention condition (mean = 0.12), $F(1, 31) = 5.92$, $MSE = 0.02$, $p < .03$. There was also a main effect for size, with participants showing higher beta values (a stronger tendency towards "no" responses) in the large (mean = 0.22) than the small condition (mean = 0.08), $F(1, 31)$, $MSE = 0.05$, $p < .002$. These results may be explained by a greater number of misses in the imagery condition, compared to the attention condition, and in the large square condition compared to the small square condition. No other effects were significant.

The analyses of the questionnaire data did not reveal any significant findings, and thus we do not report those data.

## DISCUSSION

We compared the effects of varying the size of the stimulus on which we asked participants to perform either an attention or an imagery task. We reasoned that if the size manipulation affected the two types of functions differently, we could rule out the possibility that imagery and attention rely on identical processing. Our results confirmed that imagery and attention can be dissociated.

This result is not surprising, for many reasons. First, the claim that imagery is nothing more than focused attention fails to account for the many mental imagery results obtained when participants' eyes are closed (see, for example, Kosslyn et al., 2006, for a review). Although Pylyshyn's (1989, 1998, 2003) spatial indexing explanation might be considered plausible when eyes are open, it is unclear how such a system would work when no indexes were visible.

In addition, several studies have compared attention and imagery, and the results have suggested that they differ. Slotnick, Thompson, and Kosslyn (2005) showed that when participants are asked to visualise a flickering checkerboard wedge rotating, the retinotopic activation maps, as measured by functional magnetic resonance imaging (fMRI), more closely resemble retinotopic perceptual maps (resulting from actual viewing of the stimuli) than when participants are asked to pay attention to the region of space that would be occupied by the checkerboard.

In addition, we note that dot detection was less efficient in the imagery condition than in the attention condition. Though this result may appear to provide complementary evidence that the two functions are distinct, we must consider other interpretations. For one, this finding may simply reflect the increased effort or cognitive load required to perform two tasks at once: In the imagery task, participants are required both to detect the dot and to visualise and evaluate an image. Dot detection may require more time in such cases simply because performing both tasks is more effortful, and fewer resources can be devoted to each. Similarly, participants may require more time to detect the dot during imagery because there is an additional level of executive processing.

Furthermore, this result may represent a Perky effect, whereby visual imagery interferes with visual perception. The conditions found to be most favourable for the Perky effect to occur are present in this paradigm: Ishai and Sagi (1997) found that imagery/perception interference was greatest when images of common objects were formed from long-term memory as was the case in our study rather than short-term memory. Craver-Lemley and Arterberry (2001) showed that interference effects were strongest when the image overlapped the percept in a dot detection task. Although, as mentioned earlier, attention has been found to influence the Perky effect under some conditions, there is consensus that the effect cannot be wholly explained by attention (Craver-Lemley & Arterberry, 2001).

How, then, should we explain that attention and imagery may interact in some cases, as demonstrated by Craver-Lemley and Reeves (1992), or the visual indexing results shown by Pylyshyn (see, for example, Pylyshyn, 2003)? We propose that attention may be an important component in imagery generally—one must, after all, pay attention to the object in one's image and its component parts in order, for example, to inspect the object in the image. Just as one would not replace the concept of ''perception'' with that of ''attention'' simply because attention is used in perception, one should not replace the concept of ''imagery'' with ''attention'' simply because attention plays a role in processing mental images. Moreover, attention may be particularly important in certain forms of imagery that rely on external visual stimuli and on spatial locations, such as when one pays attention to a tiled floor and sees patterns of numbers formed by the tiles.

However, when there are no external stimuli to guide one's image, and the image features a complex shape that must be created from memory and either projected onto a blank screen or produced when the eyes are closed, this process cannot be explained by appealing to attention allocation. For example, the complex, coloured, and textured features of a high-resolution image of an animal cannot be created on the basis of differential distribution of attention. The results of the present study support this observation: Imagery and attention are distinct cognitive phenomena.

Original manuscript received October 2009
Revised manuscript received January 2010

## REFERENCES


Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers*, *25*, 257–271.

Craver-Lemley, C., & Arterberry, M. E. (2001). Imagery-induced interference for a detection task. *Spatial Vision*, *14*, 101–119.

Craver-Lemley, C., & Reeves, A. (1992). How visual imagery interferes with vision. *Psychological Review*, *99*, 633–649.

Eriksen, C. W., & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception and Psychophysics*, *40*, 225–240.

Grossberg, S. (2000). How hallucinations may arise from brain mechanisms of learning, attention, and volition. *Journal of the International Neuropsychological Society*, *6*, 583–592.

Hopfinger, J. B., & West, V. M. (2006). Interactions between endogenous and exogenous attention on cortical visual processing. *NeuroImage*, *31*, 774–789.

Ishai, A., Haxby, J. V., & Ungerleider, L. G. (2002). Visual imagery of famous faces: Effects of memory and attention revealed by fMRI. *NeuroImage*, *17*, 1729–1741.

Ishai, A., & Sagi, D. (1997). Visual imagery: Effects of short- and long-term memory. *Journal of Cognitive Neuroscience*, *9*, 734–742.

Kosslyn, S. M. (1975). Information representation in visual images. *Cognitive Psychology*, *7*, 341–370.

Kosslyn, S. M., & Alper, S. N. (1977). On the pictorial properties of visual images: Effects of image size on memory for words. *Canadian Journal of Psychology*, *31*, 32–40.

Kosslyn, S. M., & Thompson, W. L. (2003). When is early visual cortex activated during visual mental imagery? *Psychological Bulletin*, *129*, 723–746.

Kosslyn, S. M., Thompson, W. L., & Ganis, G. (2006). *The case for mental imagery*. New York: Oxford University Press.

Offen, S., Schluppeck, D., & Heeger, D. J. (2009). The role of early visual cortex in visual short-term memory and attention. *Vision Research*, *49*, 1352–1362.

Pani, J. R. (2002). Mental imagery is simultaneously symbolic and analog. *Behavioral and Brain Sciences*, *25*, 205–206.

Pylyshyn, Z. W. (1989). The role of location indexes in spatial perception: A sketch of the FINST spatial-index model. *Cognition*, *32*, 65–97.

Pylyshyn, Z. W. (1998). The role of visual indexes in spatial vision and imagery. In R. Wright (Ed.), *Visual attention* (pp. 215–231). New York: Oxford University Press.

Pylyshyn, Z. W. (2002). Mental imagery: In search of a theory. *Behavioral and Brain Sciences*, *25*, 157–238.

Pylyshyn, Z. W. (2003). *Seeing and visualizing: It's not what you think*. Cambridge, MA: MIT Press.

Silver, M. A., Ress, D., & Heeger, D. J. (2005). Topographic maps of visual spatial attention in human parietal cortex. *Journal of Neurophysiology*, *94*, 1358–1371.

Slotnick, S. D., Thompson, W. L., & Kosslyn, S. M. (2005). Visual mental imagery induces retinotopically organized activation of early visual areas. *Cerebral Cortex*, *15*, 1570–1583.