Is ambiguity detection in haptic imagery possible? Evidence for Enactive imaginings

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Abstract

A classic discussion about visual imagery is whether it affords reinterpretation, like discovering two interpretations in the duck/rabbit illustration. Recent findings converge on reinterpretation being possible in visual imagery, suggesting functional equivalence with pictorial representations. However, it is unclear whether such reinterpretations are *necessarily* a *visual-pictorial* achievement. To assess this, 68 participants were briefly presented 2-d ambiguous figures. One figure was presented visually, the other via manual touch alone. Afterwards participants mentally rotated the memorized figures as to discover a novel interpretation. A portion (20.6%) of the participants detected a novel interpretation in visual imagery, replicating previous research. Strikingly, 23.6% of participants were able to reinterpret figures they had only felt. That reinterpretation truly involved haptic processes was further supported, as some participants performed co-thought gestures on an imagined figure during retrieval. These results are promising for further development of an Enactivist approach to imagination.

Keywords: visual imagery; haptic imagery; gesture; enactivism; the imagery debate

Introduction

Early phenomenological observations concerning voluntary visual imagery suggested that nothing new can be discovered in visual imagery that was not present in the intention to imagine to begin with (Sartre, 1940). This fits Descriptivist renderings of visual imagery (Pylyshyn, 2002), where visual imaginings have a fixed mode of presentation, and are "images under a description" (Fodor, 1975, p. 191). This view gained substantive empirical traction (in part) by research showing that when participants memorized an ambiguous figure under a particular percept (e.g., duck), they were unable to discover an alternate novel interpretation (e.g., rabbit) when retrieving the ambiguous figure in visual imagery (Chambers & Reisberg, 1985; Slezak, 1991). These results were obtained even though the memory of the figure was detailed enough to draw it out, and which allowed for subsequent ambiguity detection when perceiving the drawing.

Subsequent research within the ambiguity detection paradigm showed that the previous studies may have employed too difficult ambiguity examples (e.g., duck/rabbit figure), and failed to properly inform participants by providing an ambiguity example (Brandimonte & Gerbino, 1993; Finke, Pinker, and Farah, 1989; Hyman & Neisser, 1991). One of those studies showed an ambiguity detection rate of 40% with slightly less complex figures as the classic duck/rabbit figure and providing an ambiguity example (Peterson, Kihlstrom, Rose, & Glisky, 1992). Some shortcomings of previous studies that found positive findings were resolved by Mast and Kosslyn (2002), who noted that participants might have been alerted by the ambiguity of the figures during perception as they were shown an ambiguous figure before memorizing the target figure. In their study they found that 44% of the participants were able to detect an alternative interpretation while excluding possible confounds of ambiguity detection in perception rather than imagery.

In a recent study we have expanded upon this research (Kamermans, Pouw, Mast, & Paas, under review). Participants in Mast and Kosslyn's (2002) study were provided partial visual cues of the ambiguous figure during imagination. Therefore, it could not be fully excluded that some raw sensory information is necessary for ambiguity detection via imagery to occur, allowing for the possibility that ambiguity detection via imagery alone is impossible after all. In our previous study however, we found that ambiguity detection is possible without visual cues as well (30% detection rate), while excluding other possible confounds such as ambiguity detection during perception rather than retrieval in imagery.

The ambiguity detection paradigm has been primarily regarded as being important for The Imagery Debate. This is because, in contrast to the Descriptivist approach, the other contender in The Imagery Debate – the Quasi-pictorial account (Kosslyn, 2002) - explicitly argues for the possibility of ambiguity detection. On such an account, visual imaginations are constituted by internal representations that are *experienced as* and *function like* pictorial representations (drawings, diagrams, etc.). As such, analogous to pictures, the representational content of visual images are not intrinsically fixed, rather the mental image preserves the "raw" visual-pictorial information of the previously seen object which is open to reinterpretation.

In summary, there is converging evidence that visual imagination allows for similar re-interpretative feats as pictorial representations (Mast & Kosslyn, 2002; Kamermans et al., under review). Such evidence has been mainly interpreted as a win for the Quasi-pictorial account over the Descriptivist account (Mast & Kosslyn, 2002). Yet, although reinterpretation in mental imaginings might afford similar feats as pictorial representations (e.g., drawings), it need not be the case that imagination functions exactly like visual-pictorial representations. In fact, imagery-based reinterpretation need not be visual-pictorial at all.

Enactive Imaginings

Indeed, Quasi-pictorial and Descriptivist accounts of mental imagery are not the only game in town (Foglia & O'Regan, 2016). There are also views that promote an Enactive view of sensory perception and imagination (Hurley, 2002; O'Regan & Noe, 2001; Thomas, 1999)[1]. Our conception of the Enactive position in relation to imaginings, is that imaginings are something we do rather than an internal state; the success of an imagining is not (primarily) mediated by internally stored knowledge of properties of the object imagined, but rather by a pre-reflective understanding of sensori-motor relations that would hold if the object would be present. The enactive logic is that since *perception* is an accomplishment of an active embodied system (Gibson, 2014) so too must *perceptual imagination* be constituted in a practical understanding of the sensori-motor relations that would hold when perceiving some object.

Evidence closely in par with an Enactive view concerns findings that show a functional role for eye-movements in visual imagination (Brandt & Stark 1997; Laeng & Teodorescu 2002; Spivey & Geng, 2001). Note, that the functional role eye-movements seem to have in visual imagination is achieved even though eye-movements themselves do not provide visual information in a classic sense at all, e.g., eye-movements also occur and affect visual imagery when eyes are closed (Spivey, Tyler, Richardson, & Young, 2000). Note as such that although the Quasi-pictorial account could be invoked here to explain the eye-movements (as the eye-movements interact with supposed internally stored *visual* information of the object), it is difficult to explain the *function* of eye-movements which provide no visual information in the classic sense. It is precisely because an Enactive view does not adopt a classic view of perception that it is able to recognize that (pre-reflective knowledge of) bodily movements constitute perception and imagination (O'Regan & Noe, 2001; Hurley, 2002). Imagination, on such a construal, involves being attuned to sensori-motor *potentialities* of a particular object imagined (Thomas, 1999; O'Regan & Noe, 2001). In visual imagery this attunement seems to be achieved in part through reenacting eye movements (a co-constituent of visual perception).

[1] Enactive accounts may be disentangled from each other on the basis of their differing commitment to the *necessary* involvement of non-neural bodily states in mental imagery (see Foglia & O'Regan, 2016; cf. Thomas, 1999). For the purposes of the present paper the commonalities rather than the differences between these approaches are highlighted.

Present study

In the current study participants memorize two figures in succession for 30 seconds. Both of these figures have an alternate interpretation when rotated 180 degrees (i.e., figures are ambiguous). One of these figures is provided visually, the other via touch alone (i.e., haptic perception). It is then assessed whether participants are able to find the alternate interpretation for each figure in their imagination by mentally rotating the memorized figure.

As a further extension of the possibility of ambiguity detection in *visual* imagery we assess here whether participants can perform visual reinterpretations without being provided with an ambiguity example (cf. Kamermans et al., under review). However, the most important extension relative to previous research that we emphasize in this article, is the assessment of whether ambiguity detection can be performed in *haptic* imagery as well. That is, similar to visual imagery, can ambiguity be detected upon a mental imagining that is based on an ambiguous figure that was explored via touch?

Importantly, it could be that feeling a figure allows for ambiguity detection in imagery only insofar participants are able to reconstruct visual information based on this haptic perception. If true, ambiguity detection is always performed on visual information. On such a construal it is plausible that ambiguity detection rates of visually perceived figures, is greater than when haptically perceiving figures. After all, if ambiguity detection is a visual achievement, having had direct visual access as opposed to second-hand access (visual reconstruction via haptic perception) would improve the quality of the mental image, and hence improve re-interpretability. Therefore, next to assessing the possibility of ambiguity detection per condition individually, we will assess possible differences in detection rate between the haptically and visually perceived figures that would be predicted if reinterpretation in imagery is strictly a visual-pictorial achievement.

Additionally, in light of an Enactive approach to sensory perception and imagination, and our previous theoretical efforts concerning the cognitive function of co-thought gesture (Pouw, de Nooijer, van Gog, Zwaan, & Paas, 2014), we anticipated to observe co-thought (i.e., silent) hand-gestures that enacted interaction with the object during haptic imagery. That is, similar to research showing that eye-movements appear to co-constitute visual imagination, so too might manual movements co-constitute haptic imagery processes. Therefore, in the current study we explored manual gestures that occur when retrieving the haptically (as well as visually) memorized figure.

Method

Participants & Design

Sixty-eight participants were tested (61 female, *Mage* = 20.03 years, *SDage* = 3.36 years, range 17-37 years)[2]. Recruitment targeted both Dutch and non-Dutch students all of whom received instructions in English. The participants were enrolled in courses taught in English at the Erasmus University Rotterdam. All of the participants took part in the experiment for course credits.

The study had a within-subject design (Visual vs. Haptic Condition; order counterbalanced) using two test figures counterbalanced over condition assignment. Ambiguity detection rate was the main dependent variable. Additionally we assessed co-speech and co-thought gesture occurrences.

Materials

Test Figures Two ambiguous test figures were cut out from high density foam sheets, similar to Kamermans et al. (under review). The figures were designed by Leo Burnett (2015) for the "Upside Down" campaign retrieved from Google images and further modified by us. Each figure had two readily perceivable interpretations (see figure 1). An alternate interpretation could be discovered by rotating the figure 180 degrees.

Figure 1. Line drawings of the seal/doe, and the penguin/giraffe test figure. As can be seen, one interpretation always showed the *body* of an animal and the second interpretation the *head* of a different animal.

Video Recording Performance was recorded using a JVC Everio GZ-MG130 camcorder, to assess gesture occurrence and inspection of the behavioral data when necessary.

Demographics and Control Questions Participants reported their age, sex, and native language. To assess participants' beliefs about the nature of the experiment the following questions were included: "What do you think was the purpose of the current study? (If you have no idea, no answer is necessary)", and "What do you think the researchers are expecting to discover with the current study? (If you have no idea, no answer is necessary)". Finally, the experimenter would explicitly ask participants who reported reinterpretation of one or two figures whether they had noticed the alternate interpretation during memorization or newly discovered it in visual imagery.

[2] We failed to obtain age for two participants.

Procedure

Participants were tested individually and were told that they took part in a study about visual memory and memory of touch. The experiment consisted of a memorization phase and a testing phase.

In the memorization phase two figures were presented successively (order counterbalanced). Participants were informed that they would be given 30 seconds to inspect the figure and memorize it. In the Visual Condition versus the Haptic Condition participants were only allowed to see or touch the figure, respectively. For the Haptic Condition participants felt the contours of the figure which was presented under a card-board box that prevented visual inspection of the figure. The respective figure assigned to the haptic condition was horizontally attached via velcro-tape on a wooden base. The wooden base was shown to participants as to inform them how the figure would be placed on top of it (it was stressed that the wooden base was not the object of inspection). Participants were informed not to move the figure on the wooden base (experimenter ensured that orientation of the figure was not altered, which was assessable via an opening in the card-board box at the experimenter side).

After each presentation of a figure, the participants were asked what they had seen or felt (depending on condition) and the experimenter noted down the response. If participants reported a) two or more distinct interpretations or b) only the interpretation that belonged to the 180 degree alternative orientation, the associated testing phase would be skipped as ambiguity was detected prematurely (a) or signaled (b) during memorization.

After memorizing the two figures, in the subsequent testing phase participants mentally retrieved the memory of each figure consecutively (order of retrieval counterbalanced). They retrieved figures with their eyes closed, as to ensure that visual input during retrieval was consistent between participants. Once participants indicated that they had brought back their memory of the respective figure, the experimenter would inform them that this figure had another interpretation next to the interpretation they already gave. Participants were told that the alternate interpretation could be discovered by rotating the mental image 180 degrees. Participants were given no time restrictions in discovering the alternate interpretation (reaction times were timed however, but were not of special interest).

Performance and Scoring

An answer was considered correct in case the same interpretation was given by another participant in the respective condition (visual or haptic) of the memorization phase. For example, the answer "cow" for the head (doe) orientation of the seal/doe figure in the haptic condition would be considered correct if another participant had reported the same answer in the memorization phase for the haptic condition and the same orientation. For the main confirmatory analysis, we chose for checking answers in the congruent modality because the crucial research question is about the continuity between perception and imagination, and this is distorted if both modalities will track properties of objects idiosyncratically.

Note therefore, participants were primarily their own raters in this study, minimizing post hoc experimenter decisions. However, similar to our procedure in Kamermans et al. (under review) we decided that in two cases answers should be counted as correct/incorrect even though these specific interpretations were (not) named by other participants. Namely, we counted as correct "Walrus/Seal" in the haptic condition for the figure seal and the "letter Y" (which partially overlapped with "Y stick") as an incorrect combination in the haptic condition for the figure seal. Note, that these post-hoc choices do not affect interpretation of the results.

Results

Interpretations

In Table 1 all the interpretations are given that overlapped between participants in the perception and testing phase (and therefore scored correct).

Table 1: Overlapping (re)interpretations

Visual Condition	
Giraffe	Deer, Giraffe
Doe	(Baby) cow
Penguin	Penguin, Bird
Seal	Seal
Haptic Condition	
Giraffe	Tree, Flower
Doe	Deer, Aeroplane, Bird, Propeller
Penguin	Penguin, Fish, Human Being
Seal	Sea Lion, Walrus/Seal*, Bird

Note. Overlaps between perception during memorization and mental retrieval of figures between participants. Asterisk pertain to post-hoc decision (1 instance).

Exclusion

A total of 46 (34%) out of 136 ambiguity detection trials were excluded as there was either premature ambiguity detection (10/46) or an interpretation was given during memorization that did not match the orientation that the figure was given in (36/46). However, we will exclude each participant data if on *any* of the two trials within participants premature ambiguity detection was obtained as this signals awareness of ambiguity during the memorization phase, 34 participants were excluded (50%). The total sample to assess ambiguity detection rates per condition thus consists of participants who were not aware in any of the trials of ambiguity in the figures during memorization, ensuring that ambiguity detection ensued in imagery. Note that such high exclusion rates are common in ambiguity detection research as to maximally control for ambiguity detection during perception rather than imagery (see e.g., Mast & Kosslyn, 2002).

Descriptives

Retrieval time Participants in the haptic condition had an average of 23.88 (*SD*=19.51) seconds to provide an interpretation or abort attempt. Participants in the visual condition took on average 27.68 (*SD*=21.23) seconds.

Haptic Imagery vs. Visual Imagery As the descriptives show in Table 2, it seems that ambiguity detection is possible both when the figure is memorized and identified visually as well as through touch alone. Furthermore, four participants were able to detect ambiguity in both the haptic and visual conditions, and seven participants only detected ambiguity in the visual (n = 4) or the haptic (n = 3) conditions. Thus data is almost completely symmetrical across conditions and our planned within subjects-test for a binary outcome reflects this, McNemar $p > 0.99$.

Table 2: Overall detection rate

	Visual	Haptic
Doe/Seal	1/12 (8.3%)	6/22 (27.3%)
Giraffe/Penguin	6/22 (27.3%)	2/12 (16.6%)
Total	**7/34 (20.6%)**	**8/34 (23.6%)**

Haptic-Visual Imagery: Effects of Crossmodal Scoring However, it could be noted that since each condition (visual vs. haptic) has its own rating system that this could affect/distort our interpretation in significant ways. As such we performed an additional exploratory re-analysis where we counted any interpretation correct if it was named in the visual *or* the haptic memorization phase (see Table 1). This revealed a McNemar significance test $p = .227$, with a detection rate of 38.2% for the visual condition and 23.6% for the haptic condition (table 3). Thus, note that the more lenient scoring system slightly inflated detection rates in the visual condition but not to a degree that the null-hypothesis could be rejected.

Table 3: Overall detection rate

	Visual	Haptic
Doe/Seal	3/12 (25%)	6/22 (27.3%)
Giraffe/Penguin	10/22 (45.5%)	2/12 (16.6%)
Total	**13/34 (38.2%)**	**8/34 (23.6%)**

Exploratory: Gesture occurrence During testing we observed that participants adopted spontaneous gestures during the testing phase when retrieving and interpreting the figure even though participants kept their eyes closed during retrieval. Firstly, participants used co-speech gestures when providing an interpretation (often accompanied by a description) of the figure 44/68 (64.7%) in the haptic condition and slightly less in the visual condition, 36/68 (52.9%). Perhaps, such co-speech gestures solely fulfill communicative purposes, as the interpretation needed to be communicated to the experimenter. However, we also found that a select few performed gestures in silence (i.e., co-thought gestures), as-if feeling the contours of the previously felt figure (3 participants in the haptic condition) and more pointing-and-tracing gestures in the visual condition (n = 3), e.g., tracing the contours of the figure on the table. Further note that when premature ambiguity detection is controlled for (sample = 34) we found that 20% (4/20) of those who gestured in the haptic condition detected ambiguity whereas 28.5% (4/14) of those did that did not gesture. Furthermore, 23.5% (4/17) of gesturing participants in the visual condition detected ambiguity as opposed to 17.6% (3/17) for non-gesturing participants.

Figure 2. Example co-thought gesture in haptic trial

Discussion

The current results replicate previous research showing that ambiguity detection in visual imagery is possible (Mast & Kosslyn, 2002; Kamermans et al., under review), i.e., when memorizing a figure under a particular percept this figure can be discovered to have another interpretation by re-inspecting it in visual imagery. This finding further extends this research in that ambiguity detection in visual imagery is possible without showing participants an example of an ambiguous figure after memorization (in contrast to Kamermans et al., under review). Further research could employ more direct comparisons of the effect of providing an ambiguity example or not after memorization on ambiguity detection rates (for a discussion on this see Peterson et al., 1992).

More importantly however, we have shown that ambiguity detection of a figure in mental imagery is possible even when the figure is explored via manual touch alone, as evidenced by the approximate 23.6% detection rate in the haptic condition ("approximate" barring different coding schemes). The important question is whether this shows that ambiguity detection was (solely) performed via *haptic imagery*, or whether exploring a figure via touch results in visual images upon which reinterpretation could be performed. This is a question that this study does not address directly.

However, in speculative vain it is striking that we did not find statistically significant differences in a within-subject test on ambiguity detection for visually or haptically explored figures. If ambiguity detection is solely performed in the visual modality of imagination, one would predict that having direct visual access to an ambiguous figure would support the quality of that imagination - hence inflating ambiguity detection - relative to figures that were only haptically perceived. However, even bearing this in mind it does not exclude that ambiguity detection was not achieved via visual imagery.

On the other hand however, we do find evidence that reinterpretation of imagined haptically explored figures is likely to involve *some* haptic processes, or at least *at times*, given that a few participants were manually reenacting manipulating an (imagined) figure. This directly relates to eye-movements (i.e., "ocular reenactments") during visual imagery. These eye-movements reenact perceptual affordances of previously *seen* figures. In the current example, manual reenactments seem to exploit manual affordances of previously *felt* figures. In sum, we find it an attractive hypothesis that - at minimum - a cross-modal visual-haptic imagination is performed when reinterpreting previously felt figures. This is in par with a host of studies showing that haptic and visual perception are co-informative (e.g., Lacey, Campbell. Sathian, 2007; Wallraven, Bülthoff, Waterkamp, van Dam, & Gaissert, 2014).

A New Imagery Debate?

As mentioned, discovery of a novel re-interpretation of a visual imagining has been regarded as supporting the Quasi-pictorial account of visual imagery (Mast & Kosslyn, 2002) and refuting the Descriptivist assumption that visual imagery is necessarily fixed under an original perceptual ascription (Chambers & Reisberg, 1985; Pylyshyn, 2001). However, on our reading, ambiguity detection can also be accounted for within an Enactive framework, where the achievement reinterpretation requires a skill-full act that is inherently unstable because of the lack of direct access (O'regan & Noe, 2001; Thomas, 1999). This constraint of imagery as inherently unstable may actually have some explanatory power over the Quasi-pictorial account. Note, for example that only a small portion (not more than 38%) of the current sample is able to reassign meaning to a mental imagining [3]. This is striking as there is reason to believe that the current figures are relatively easy and memorized up to a point that participants can accurately draw them, as previous research with shorter memorization times and more complex figures has shown (Chambers & Reisberg, 1985). Thus, if it were the case that ambiguity detection depends on internally represented pictorial information, reinterpretation rates should be much higher. If however, the achievement of gaining access to a previously seen or felt object via imagining consists in an effortful skill-based employment of a *coalition of sensory systems*, then it is not surprising that ambiguity detection is as difficult as it is. It does not require a mere retrieval and re-inspection of internally represented visual-pictorial imprints, but an attunement to sensori-motor

[3]Studies generally show low ambiguity detection rates across a range of more and less complex figures (detection rates are always less than 50%; Brandimonte & Gerbino, 1993; Hyman & Neisser, 1991; Peterson, Kihlstrom, Rose, & Glisky, 1992; Mast & Kosslyn, 2002)

contingencies when interacting with an object. Further note, that the proposed multimodality of imagery does not apply to haptic ambiguity detection alone, as our findings show that even in cases where participants reinterpret a figure in visual imagery, non-communicative gestures are recruited that exploit affordances of the figure as if it were visually present (e.g., by tracing the contour on the table during retrieval with eyes closed).

Before concluding, some shortcomings need to be shortly stressed (as to invite further research). Firstly, no causal relation can be inferred from manual action and haptic imagery at this point. We are currently performing a study that manipulates manual enactment to ascertain its role in (haptic) imagery. Secondly, although results signal that haptic processes may be directly involved in ambiguity detection of previously felt figures, the current design does not exclude the possibility that ambiguity detection is purely a visual achievement. This is because haptic perception might induce visual construals which allow for visual reinterpretation. Additionally, as mentioned by a reviewer, current participants remembered two figures that were alike in their representation of an animal body/head. This likeness might interfere with memorization of both figures, perhaps making comparison between haptic/visual conditions more problematic.

To conclude, we have provided evidence that reinterpretations in mental imagery can be achieved when figures are memorized visually or via manual touch alone. We have argued on the basis of a) the observed manual enactments during imagery, as well as b) the lack of observed differences between visual and haptic ambiguity rates, that ambiguity detection might not be purely visual-pictorial. Instead, we have speculated that visual and/or haptic imagery is mediated by a pre-reflective understanding of the sensori-motor relations that would hold were the object present.

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