Vivid Imagery is Reported Faster than Weak Imagery

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Abstract

Visual imagery and external perception rely on similar representations. However, whether the same processes underpin the subjective appraisal of both percepts and mental images is not yet known. One well-known effect in perceptual detection tasks is that people take longer to report perceptions of absence compared to presence. Vividness reports are detection-like in that participants report the presence or absence of a mental image. We therefore asked whether reports of low vividness share commonalities with reports of target absence. Across five pre-existing datasets, we report a robust negative relationship between imagery vividness ratings and reaction times: participants take longer to report the vividness of mental images when they are weak. In addition, we tentatively find that individual differences in detection asymmetries and trait imagery can predict the strength of this vividness-response time relationship. Our results may be suggestive of a shared mechanism employed across both perception and imagery that evaluates the strength of visual experience. Future research is necessary to fully characterise the mechanisms driving this effect.

Introduction

Early research on the format of mental images used reaction time to show similarities with perception. For example, in their seminal study, Shepard and Metzler showed that participants take longer to compare two differently rotated three-dimensional objects when their rotational angle is larger, similar to rotating those objects in reality (Shepard & Metzler, 1971; Tarr & Pinker, 1989). Relatedly, Kosslyn and colleagues showed that it takes more time to traverse larger distances in a mental image, such as between the feet and the head of an imagined person, versus the feet and the knees, similar to scanning in perception (Kosslyn & Ball, 1978). These observations suggested that imagery, like perception, relies on depictive representations, an idea that has now been confirmed with neuroimaging (Dijkstra, Bosch, et al., 2019; Dijkstra et al., 2020; Pearson, 2019; Siclari et al., 2017). However, while the representational overlap between imagery and perception is well known, whether appraisal of mental images shares similar cognitive mechanisms to the appraisal of external perception is not yet established.

One effect consistently exhibited in perceptual detection tasks is an asymmetry in reaction times between ‘target present’ and ‘target absent’ decisions (Kellij et al., 2021; Mazor et al., 2020, 2021, 2025; Meuwese et al., 2014). In other words, participants typically take longer to report when they did not see something compared to when they did. Importantly, this effect is also present when participants rate the visibility of visual stimuli on a graded scale, with absence of visibility taking longer than clearer experiences (Andersen et al., 2016). Effects such as these can offer important insights into the cognitive and computational processes underlying perception. For instance, one interpretation of the presence-absence asymmetry is that it reflects an asymmetric evidence accumulation procedure for decisions about presence and absence (Mazor et al., 2025).

Here, we describe a similar effect in the domain of visual mental imagery. As with the detection of present and absent stimuli in perceptual tasks, people can report the vividness of their mental imagery from weak or absent imagery to highly vivid imagery. Across five independent datasets, we reveal that reported imagery vividness is negatively correlated with the time it takes participants to report the vividness of their imagery. Like perception, reports of low vividness take longer than reports of high vividness. We further explore whether this effect is related to individual differences in presence-absence asymmetries in perceptual detection decisions and in imagery vividness. We contend that the negative relationship between vividness and reaction time may be suggestive of a shared mechanism employed across both perception and imagery that evaluates the strength of visual experience, regardless of whether it is imagined or perceived. More generally, we hope that reporting this effect will aid in constraining theories and cognitive models of mental imagery and its relationship to perception.

Materials and Methods

Datasets

We re-analysed data from four published datasets (Cabbai et al., 2023, 2024; Dijkstra, Hinne, et al., 2019; Dijkstra et al., 2025) and one unpublished pilot dataset. In each experiment, participants rated trial by trial vividness of their mental imagery. In Dijkstra et al., (2019), participants performed a binocular rivalry task during which they imagined gratings and rated their imagery vividness prior to a rivalry display. Cabbai et al. (2023) consisted of participants imagining fruits or vegetable during an attentional capture task. At the end of each trial participants reported the vividness of their imagery. In Cabbai et al. (2024), participants were asked to listen to different sounds and rate the vividness of visual mental imagery that accompanied their listening. The task underlying the unpublished pilot dataset follows closely that of Dijkstra et al. (2025a). In both these tasks, participants performed both detection and imagery tasks simultaneously. As participants viewed dynamic noise stimuli, they were asked to imagine a particular grating in the noise. At the end of each trial, they were asked to report the vividness of their imagery, and whether a grating had actually been presented or not. There were two differences between the two tasks. Firstly, in Dijkstra et al. (2025), the detection target's onset was gradual, while in the unpublished dataset target onset was immediate. Secondly, the unpublished dataset used a sliding scale from 0 to 100 to report imagery vividness, while Dijkstra et al. (2025) used a 1 to 4 scale. Table 1 describes each experiment, including the imagined stimuli, the sample size, and the vividness rating scale. Further details of each task can be found within the original publications.

Analyses

Data were analysed in RStudio 1.4.1106 using R version 4.1.0 and *afex* 1.4-1 (Singmann et al., 2012). Trials with reaction times shorter than 200ms and longer than 10s were removed, as were trials where reaction times fell 3 SD outside the mean. For Dijkstra et al. (2019) and the Imagery and Perception Pilot Data, the sliding bar scales were split into quartiles, transforming vividness ratings to a 1 to 4 scale within each participant. Linear mixed effects models were constructed for each dataset with the reaction time for imagery vividness ratings as the dependent variable. Individual participants were modelled with random intercepts and slopes for the main effect of vividness on reaction time. In all models, covariates were z-scored prior to estimating the model.

Experiment	Sample Size	Trials Per Subject	Imagined Stimuli	Vividness Scale	Study Type
Dijkstra et al. (2019)	69	220	Red/Blue Gratings	Sliding bar [-150 – 150]	In Person
Cabbai et al. (2023)	121	240	Fruits and Vegetables	[1 – 5]	Online
Cabbai et al. (2024) *Supplementary Pilot Experiment 2*	75	24	Living and Non-Living Phenomena (e.g. seagulls, traffic, dog, airplane etc.)	[1 – 5]	Online
Dijkstra et al. (2025)	24	384	Left/Right Gratings	[1 – 4]	In Person
Imagery and Perception Pilot Data (2025)	34	Mean = 252.91; Min = 168; Max = 288	Left/Right Gratings	Sliding bar [0 – 100]	Online

Table 1. Experimental details of different datasets.

Results

Imagery Vividness is Negatively Correlated with Reaction Time

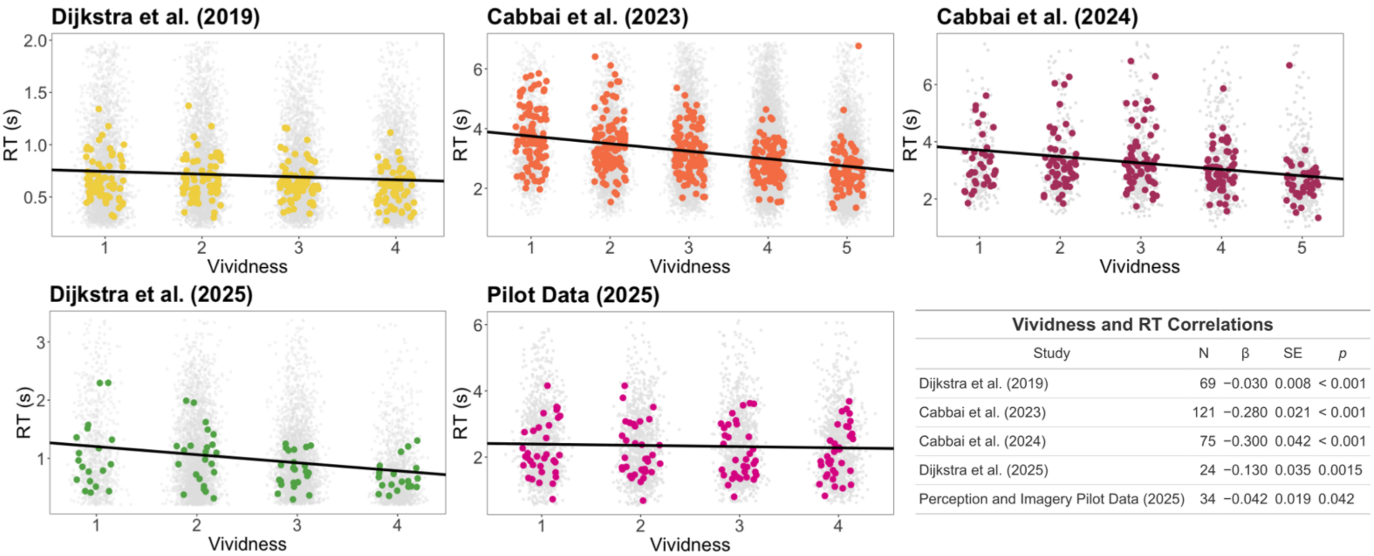
Across all five datasets, the vividness of participants' imagery was negatively correlated with the time taken to report the vividness of imagery (**Figure 1**). In other words, it took individuals longer to report imagery vividness when their imagery was less vivid. Statistical results are summarised in **Figure 1** (bottom-right). In all datasets, we observed a significant negative relationship between the vividness of imagery and the time taken to report it (Dijkstra et al. (2019): β = -0.03, SE = 0.008, p < .001; Cabbai et al. (2023): β = -0.28, SE = 0.021, p < .001; Cabbai et al. (2024): β = -0.30, SE = 0.042, p < .001; Dijkstra et al. (2025): β = -0.13, SE = 0.035, p = .0015; Perception and Imagery Pilot Data (2025): β = -0.042, SE = 0.019, p = .042).

We performed a control analysis to ensure the relationship between imagery vividness and reaction time was not driven by an unequal number of trials across vividness ratings. To do this, within each dataset, we pseudorandomly under sampled trials until the trial count was equal across vividness ratings. The negative correlation remained significant in all datasets (Dijkstra et al. (2019): β = -0.03, SE = 0.008, p < .001; Cabbai et al. (2023): β = -0.28, SE = 0.019, p < .001; Cabbai et al. (2024): β = -0.21, SE = 0.052, p < .001; Dijkstra et al. (2025): β = -0.13, SE = 0.034, p = .0013; Perception and Imagery Pilot Data (2025): β = -0.043, SE = 0.020, p = .039.

Relating Imagery Vividness, Reaction Time, and Detection Asymmetries

If the negative relationship between imagery vividness and reaction time is driven by the same mechanism governing asymmetries in perceptual detection responses, we might expect to see a correlation between these effects over participants, such that participants who show a greater detection asymmetry also show a stronger vividness-reaction time correlation. In two datasets (Dijkstra et al., 2025; Perception and Imagery Pilot Data., 2025), participants were simultaneously asked to imagine and detect grating stimuli throughout each trial. Before participants reported the vividness of their imagery, they were asked to report whether they saw a grating presented. In line with previous research identifying an asymmetry in reaction times for present and absent detection responses (Kellij et al., 2021; Mazor et al., 2020, 2021, 2025; Meuwese et al., 2014), there was a general trend for participants to take longer to report that a grating was absent compared to when participants believed it to be present (**Figure 2A,**

left; Dijkstra et al. (2025) : Mean$_{Absent}$ = 714ms, Mean$_{Present}$ = 642ms, t(23) = 1.82, *p* = .08; **Figure 2A, right**; Imagery and Perception Pilot Data (2025): Mean$_{Absent}$ = 1130ms, Mean$_{Present}$ = 1003ms, t(33) = 2.97, *p* = .006).



Vividness and RT Correlations

Study	N	β	SE	*p*
Dijkstra et al. (2019)	69	−0.030	0.008	< 0.001
Cabbai et al. (2023)	121	−0.280	0.021	< 0.001
Cabbai et al. (2024)	75	−0.300	0.042	< 0.001
Dijkstra et al. (2025)	24	−0.130	0.035	0.0015
Perception and Imagery Pilot Data (2025)	34	−0.042	0.019	0.042

Figure 1. Imagery reaction time is negatively correlated with imagery vividness. Across all five datasets, we observed a significant main effect of imagery vividness on the time taken by participants to report the vividness of their imagery. Individual points on the scatterplots represent individual trials, with random slopes and intercepts used to model different participants. Coloured dots show median reaction time per vividness rating for each subject. Transparent grey dots represent individual trials. Black lines illustrate multilevel model fits. Right: summary of mixed model results for each dataset.

To test whether an individual's asymmetry in detection responses was associated with their asymmetry in vividness judgements, we computed the magnitude of individual participants' detection asymmetry by subtracting the mean reaction time for present responses from the mean reaction time for absent responses per participants. In Dijkstra et al. (2025), adding individual participant's detection asymmetry as a covariate in our model of imagery vividness on imagery reaction time again resulted in a main effect of vividness on reaction time (β = -0.12, SE = 0.031, *p* < .001) as well as a main effect of detection asymmetry on reaction time (β = 0.18, SE = 0.063, *p* = .007), such that people who were slower in target-absent responses in the detection task were overall slower in giving vividness ratings. Importantly, the interaction between detection asymmetry and imagery vividness was also significant (β = -0.08, SE = 0.031, *p* = .019; **Figure 2B**). To probe this interaction further, we computed simple slopes for the effect of vividness on reaction time at three levels of detection asymmetry: one standard deviation below the mean (−1 SD), the mean (0 SD), and one standard deviation above the mean (+1 SD). This revealed an increasing strength of the vividness-reaction time relationship as participants' detection asymmetries grew (-1 SD: β = -0.04, SE = 0.044, *p* = .33; mean: β = -0.12, SE = 0.031, *p* = .0001; +1 SD: β = -0.20, SE = 0.043, *p* < .0001). In other words, participants who took longer to report target absence (compared to presence) in perception also took longer to report weak (compared to vivid) imagery. To illustrate this effect, we binned participants' asymmetry into three quantiles: weak, medium, and strong and plotted the relationship between vividness and reaction time for each (**Figure 2B**). Adding participants' detection asymmetries as a covariate to our model for the Imagery and Perception (2025) pilot data also revealed a significant main effect of vividness on imagery reaction time (β = -0.04, SE = 0.02, *p* = .039), however the main effect of detection asymmetry (β = 0.25, SE = 0.131, *p* = .066) and the vividness x asymmetry interaction (β = -0.03, SE = 0.02, *p* = .134) were not significant (**Figure 2C**). In both datasets, using participants' median reaction times to compute their detection asymmetry did not influence the statistical significance of the vividness x detection asymmetry interaction term (Dijkstra et al., 2025: β = -0.08, SE = 0.03, p = .012; Pilot Data: β = -0.03, SE = 0.021, p = .175), establishing that outliers in participants' detection reaction times were not driving or masking this result.

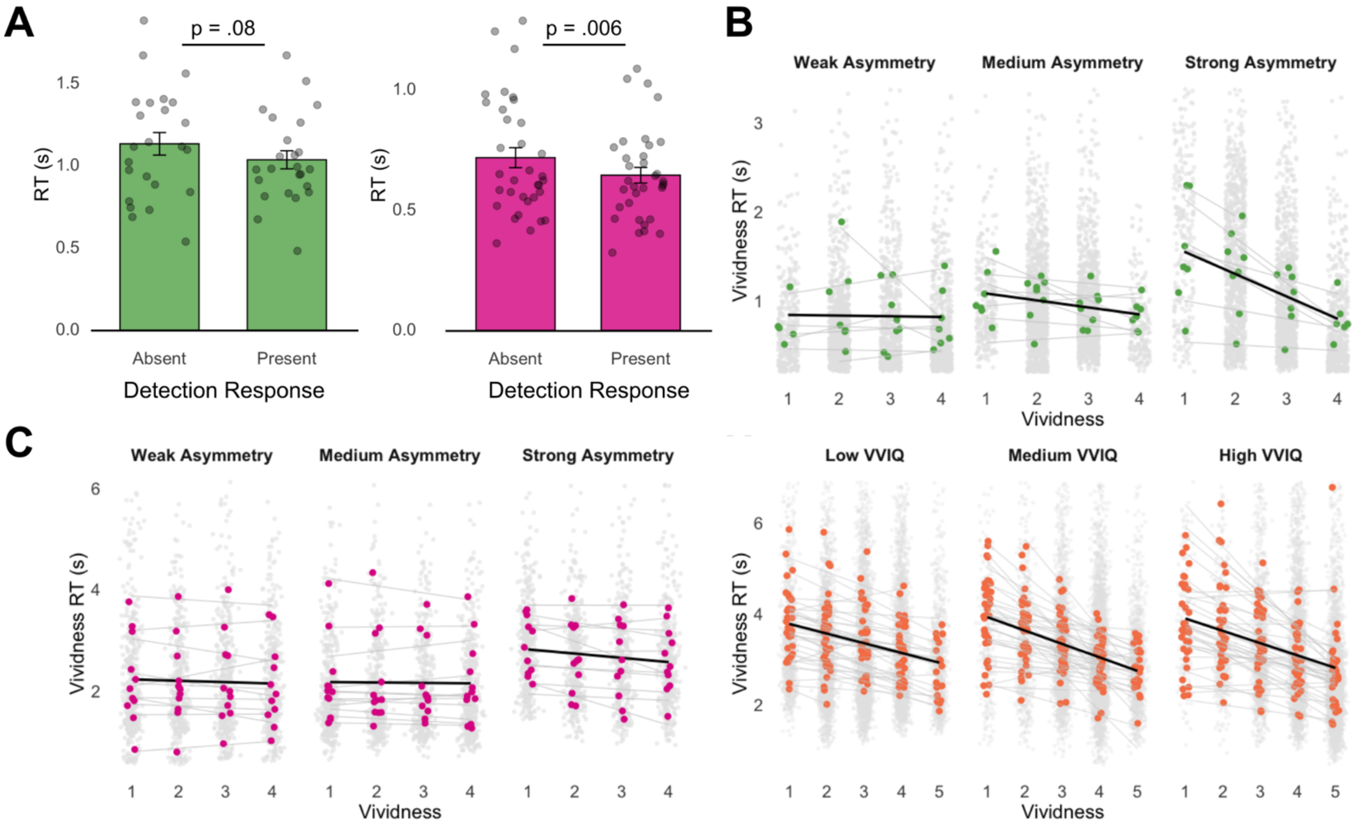


Figure 2. Asymmetries in Detection Responses and VVIQ Interact with Imagery Vividness and Reaction Time Relationship. A: Participants generally take longer to report a stimulus was absent than when it was present in two tasks with perceptual detection components. *Left:* Dijkstra et al. (2025); *Right*: Imagery and Perception Pilot Data (2025). **B**: Participants in Dijkstra et al. (2025) with greater asymmetry between present and absent detection responses show an increased negative relationship between imagery vividness and reaction time. Data are binned into weak, medium, and strong detection asymmetry groups for illustration purposes only. **C**: The interaction between detection response asymmetry and imagery vividness did not replicate in the Imagery and Perception Pilot Data (2025). **D**: Individuals with more vivid trait imagery showed an increased negative relationship between imagery vividness and reaction time in Cabbai et al. (2023). Data are binned into weak, medium, and strong VVIQ groups for illustration purposes only. Coloured points represent individual subject means. Transparent grey points illustrate individual trials. Transparent grey lines show linear models fit to individual subjects, for visualisation purposes only. Black lines reflect linear regression models fit to subject means per each detection asymmetry and VVIQ group, for visualisation purposes only.

Relating Imagery Vividness, Reaction Time, and Trait Imagery

A further interesting question is whether an individual's trait imagery impacts the relationship between vividness judgements and reaction times. For example, it might be the case that people with very vivid imagery have different expectations regarding the vividness of their mental images relative to those with weaker imagery, which might lead them to report vivid imagery faster than weak imagery. To explore whether participants' self-reported trait imagery strength (as measured by VVIQ (Marks, 1973)) was related to the relationship between imagery vividness and reaction time, we added participants' VVIQ scores to the model for two datasets (Cabbai et al., 2023; 2024). In Cabbai et al. (2023), adding VVIQ as a covariate resulted in a significant main effect for vividness on reaction time (β = -0.27, SE = 0.22, p < .001) and a significant interaction between vividness and VVIQ (β = -0.06, SE = 0.023, p = .012, **Figure 2D**). Computing simple slopes at different levels of VVIQ showed the vividness and reaction time relationship to increase in strength as VVIQ increased (-1 SD: β = -0.22, SE

= 0.034, $p < .0001$; mean: β = -0.28, SE = 0.022, $p < .0001$; +1 SD: β = -0.34, SE = 0.030, $p < .0001$). These results demonstrate that as participants' trait imagery increases, the relationship between imagery and reaction time becomes more negative. The main effect of VVIQ on imagery reaction time was not significant (β = 0.006, SE = 0.068, p = .92), meaning trait imagery did not correlate with the general speed of participants' responses. For illustration purposes, we binned participants into three quantiles for low, medium, and high VVIQ scores and plotted the relationship between imagery vividness and reaction time for each quantile (**Figure 2D**). To confirm that this effect was not a result of people with high VVIQ scores reporting weak imagery on fewer trials, we binned trial-based vividness ratings into low, medium, and high vividness within each subject and balanced trial numbers within each of these bins by pseudorandomly undersampling trials in each bin to match the bin with the lowest trial count. This effectively removes the impact of different trial counts for different vividness ratings between people with low and high VVIQs. Running the model on this balanced data again revealed a significant interaction (β = -0.03, SE = 0.011, p = .015), demonstrating that unequal trial numbers were not driving the interaction between VVIQ and vividness. Adding VVIQ as a covariate to the model for Cabbai et al. (2024) revealed a significant main effect of vividness (β = -0.32, SE = 0.065, $p < .001$) and VVIQ (β = 0.13, SE = 0.066, p = .045). However, the interaction between VVIQ and vividness was not significant in this dataset (β = -0.04, SE = 0.048, p = .36).

Discussion

Perception and mental imagery rely on similar representations (Dijkstra, Bosch, et al., 2019; Dijkstra et al., 2020; Pearson, 2019; Siclari et al., 2017). However, the extent to which they rely on similar appraisal mechanisms remains underexplored. A robust asymmetry in perceptual detection is that it takes longer to report that a stimulus is absent than to report that it is present. Here, we report a novel observation with respect to the appraisal of mental images: similar to perception, less vivid imagery takes longer to report than highly vivid imagery (**Figure 1**). Furthermore, in certain datasets we show that this effect is strengthened both for individuals showing a greater asymmetry in response times in perceptual detection decisions, as well as those with greater trait imagery vividness (**Figure 2**).

The relationship between reaction times in imagery and perception has been used previously to argue for a functional overlap between the two domains. For instance, it is known that during perception, foveated targets are subject to faster responses than those in the periphery (Chelazzi et al., 1988). The same has been shown for imagery, where participants are faster to report the formation of central mental images compared to those in the periphery (Marzi et al., 2006). Such findings lend support to models describing imagery as recruiting similar computational mechanisms to visual perception, specifically its retinotopic organisation. Additionally, across a range of low-level visual features, response times for imagery and perception are correlated (Broggin et al., 2012). For instance, participants are faster to report the formation of mental images of shapes when they are of high, rather than low, luminosity. The same pattern observed during perceptual detection of such shapes. Here, we extend this line of work to incorporate the speed at which people report their imagery to be vivid or not and relate this to established behavioural signatures found in perceptual detection tasks.

The underlying mechanism that causes the symmetry in reaction time effects between imagery and perception remains unclear. Intuitively, one might believe that, since mental images are initiated internally and thus the mechanisms that determine an image's qualities are also internal, we should have immediate access to its qualities from a direct read-out of the image-forming mechanisms. If this were the case, any differences in reaction time would be due to differences in other processes unrelated to the evaluation of mental images, such as the time it takes to generate the image. However, in our study, this would suggest a rather counterintuitive effect: it takes more time to form a weak image than to form a vivid image.

Alternatively, an explanation in terms of differences in evaluation time for weak and vivid images can be found in a recent theoretical account for the asymmetry in reaction time between present and absent responses (Mazor, 2025; Mazor et al., 2025). According to this proposal, the reaction time is a product of distinct mechanisms for the evaluation of absence compares to presence. In the model, evidence for absence can never be obtained directly by perceptual systems but instead must be inferred from a lack of positive evidence for a target. This inference follows an implicit counterfactual reasoning process of the sort ‘if it had been present, I would have seen it’ (Mazor et al., 2025). One possibility is that similar inferential mechanisms are necessary for the appraisal of mental images. Our finding that weaker images take longer to report – and that this is related to detection asymmetries in one dataset – is in line with this view, as it implies that reporting weak (or absent) mental images incurs greater processing cost than vivid (or present) images, perhaps indicative of a reliance on a similar type of inference to detect an absence of imagery.

Similar reaction time profiles across perception and imagery may also be affected by non-perceptual biases. For example, vividness ratings are often presented on linear scales meaning that responses for weak imagery are presented on the left of the screen and vivid imagery on the right. This means that differences in motor speed for different response options could contaminate reaction times. We note, however, that in three of the datasets analysed here (Dijkstra et al., 2019; Cabbai et al., 2023; Perception and Imagery Pilot Data) participants used a mouse to report their imagery vividness, meaning that disparities in reaction times for key presses from different fingers are unlikely to fully explain the effect of imagery vividness on reaction time.

The effect of perceptual and imagery vividness on reaction time may also be affected by a linguistic processing cost associated with negation (Wason, 1959, 1961). The cost of negation is defined by longer reaction times when reading or evaluating sentences including negations (e.g. ‘not’, ‘without’, etc.), and this has even been shown to occur for sentences including words with negative semantics such as ‘fewer’, ‘hardly any’, or ‘a minority’ (Clark, 1969; Just & Carpenter, 1971). It is therefore possible that reporting an absence of perceptual visibility or ‘weak’ imagery may incur the same cost and may, to some extent, drive a negative correlation between reaction time and vividness reports in perception and imagery. It is worth noting, however, that detection asymmetries in reaction time emerge also when reports of absence do not correspond to verbal negation, such as when deciding whether a stimulus was a Q or an O (Mazor et al., 2021). More empirical work is needed to elucidate the underlying mechanism in the case of vividness judgments.

To conclude, across five independent datasets, we consistently found a negative correlation between imagery vividness judgements and the time taken to report imagery vividness, a behavioural signature corresponding to response time asymmetries in perceptual detection judgements. We suggest that this effect could be due to imagery employing a similar mechanism as perception to evaluate the strength of mental images. Experiments designed to reveal the true basis of this effect are warranted, and we hope that by drawing attention to this observation future models of perception and imagery can account for the robust relationship between vividness and reaction time.

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