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Cognitive Penetration Is an Instance of Experimental Confounding — Due to the Operationalization of Perception as a Magnitude Estimation (Rather than as a Category Identification)

Nagireddy Neelakanteswar Reddy

Ahmedabad, India

Cognitive penetration is the assumption that non-sensory factors influence sensory perception at the core level of sensory processing, thus generating or modifying the contents of perception. However, the experimental instances of cognitive penetration can be argued to be instances of experimental confounding that occur due to the operationalization of perception to be a magnitude estimation activity rather than as a category identification task. The magnitudinal stimuli can confound the experiments as they tend to generate perceptual fuzziness and thus lead to non-veridical overestimations as well as underestimations of those stimuli. And, these non-veridical estimations or approximations fail to be distinguishable whether they are (sensory) perceptual errors or (non-sensory) response biases per se. Moreover, the typical cognitive-penetration-like effects will not be observed if the perception is operationalized as a category identification activity, as the categorical stimuli are not fuzzy and do not lead to response biases. Thus, the purported instances of cognitive penetration can be argued to be mere instances of experimental confounding, and thus, cognitive penetration is not a valid psychological phenomenon.

Keywords: cognitive penetration, magnitude estimation, categorical perception

Cognitive penetration is the assumption that (non-sensory) cognitive processes (such as culture, language, concepts, desires, beliefs, thoughts, memory, motivation, emotion, action) tend to penetrate (the core of) sensory processing, and thus, change the ensuing perceptual contents in line with these top–down cognitive processes (see Stokes, 2013; Zeimbekis and Raftopoulos, 2015, for an introduction). Typically, it is observed — in experiments — that the top–down

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Correspondence concerning this article should be addressed to Nagireddy Neelakanteswar Reddy, Ph.D., L1104, Casa Vyoma apartment, Sarkari vasahat road, Vastrapur, Ahmedabad, Gujarat, India, PIN code: 380015. Email: nagireddy.neel.reddy@gmail.com

cognitive factors lead to either (subjective) overestimation or underestimation of the objective stimuli (that are presented to the participants). For example, the cognitive penetration literature shows that linguistic or cultural knowledge of the colour of an object leads to an overestimation of the corresponding colour of that object (e.g., Hansen, Olkkonen, Walter, and Gegenfurtner, 2006), and bioenergetic states — such as being hungry or being encumbered by weight — lead to overestimation of spatial features such as slants and distances (e.g., Proffitt, Stefanucci, Banton, and Epstein, 2003). The proponents of cognitive penetration ascribe biological functionality to these subjective estimations or approximations — that are proprietary of cognitive penetration — by proposing that the (contextual) cognitive factors supply perceptual rulers or scales that guide the transformation of raw visual angles into (refined) percepts like distance, size, slant etc., and thus perception is scaled to these cognitive factors (Philbeck and Witt, 2015).[1] For instance, a scaling of perception in accordance with bioenergetic factors such as whether the perceiver is low in physical fitness, is fatigued, is overweight, is hungry, is unhealthy, and is physically weak etc., influences how she perceives distances and slants so that she decides — at the perceptual level itself, by virtue of cognitive penetration — to conserve energy while engaging in those energy-consuming activities like trekking and climbing. That is why, wearing a heavy backpack while trekking and climbing a hill makes the hill look — at the sensory level itself due to penetration by the bioenergetic state of carrying a backpack — steeper (Bhalla and Proffitt, 1999). Perceiving the hills to be steeper under physical weight or ill-health deters the perceiver to attempt (the energetically costly) ascent of a hill. Similarly, perceivers who attained elevated blood glucose levels due to ingestion of a sugary drink perceive — due to penetration by the bioenergetic state of elevated blood glucose — the distance to be shorter, and thus, not deterring to an energy-consuming hike (Zadra, Schnall, Weltman, and Proffitt, 2010). Thus, the assumption of cognitive penetration proposes that either perceptual overestimation or perceptual underestimation occur in accordance with the cognitive-scaling of perception that is unique (or uniquely functional) to the corresponding cognitive factor.

Furthermore, the proponents of cognitive penetration substantiate their hypothesis on the basis of an existence of downstream projections into the sensory areas in the brain (Newen and Vetter, 2017; O'Callaghan et al., 2017). According to the proponents of cognitive penetrability, the sensory areas in the brain embrace downward projections from the non-sensory areas and thus, there

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[1] Philbeck and Witt (2015) say that "Optical information specifying size, distance, and other spatial properties of objects takes the form of visual angles…. Consequently, in order to perceive dimensions such as distance, size, and slant, optical information needs to be scaled from angles to these dimensions. Because optical information about spatial properties comes in the form of angles, the scaling mechanism must be a non-visual factor" (p. 1135), and thus, the necessity of the scaling by the top–down cognitive factors.

occurs (downward) cognitive penetration. This interpretation of the presence of downward projections hinges on the research on the timing or processing latencies of neural processes in different parts of the visual system, which hints at a three-stage processing of visual perception: (1st) the feedforward sweep (100 ms after stimulus onset), (2nd) the local recurrent processing (at about 120 ms), and (3rd) the global recurrent processing (around 150–200 ms) [Lamme and Roelfsema, 2000]. At the first feedforward sweep stage (around 100ms after stimulus presentation), the signal transmission occurs from retina to inferior temporal cortex through the visual cortex areas like V1, V2, V3, and V4. Both the proponents and opponents of cognitive penetration agree that the visual processing at this stage is immune from feedback from downstream projections (and is pure bottom–up signal transmission) as it has been observed that neuronal firing in each area is at a much lower frequency than that of earlier areas, and thus "leaving no time for lateral connections and no time for feedback connections to exert their effect" (Lamme and Roelfsema, 2000, p. 572).

At the second local recurrent processing stage (around 120 ms), the information is transmitted from later visual areas (for instance, V4) to earlier ones such as V1. However, this feedback is purely within the visual areas and is not from the cognitive areas, and thus is considered local. These "top–down" influences may supply (evolved and thus phylogenetically) hard-wired "some kind of a statistical rules of the universe" (Marr, 1982, p. 185) that shape visual perception; some examples of these "statistical rules about the world" include edge detection from light differentials, depth perception from stereopsis or curvature of variations in illumination, or implementation of epipolar constraint, etc. (Zeimbekis and Raftopoulos, 2015). Although some researchers (figuratively) use terms like "assumptions" and "inferences" (e.g., Helmholtz, 1962; Spelke, 1990) to refer to these (local) hard-wired statistical rules that support visual transformations, one should cautiously note that these hard-wired statistical rules are not implementing any (literal) propositional inferences (e.g., Dennett, 1971) and they "are not available to introspection; they function outside the realm of consciousness, and their operations cannot be attributed as acts to perceivers" (Zeimbekis and Raftopoulos, 2015, p. 15); thus, some researchers use neutral terminologies like "formation principles" (Burge, 2010) and "operational constraints" (Raftopoulos, 2015) to refer to the hard-wired statistics and avoid the connotation of their being conceptual/cognitive inferences or assumptions. As these hard-wired statistical "assumptions" are intrinsic (or local) to the visual areas themselves and work independently of the (nonlocal) top–down cognitive or conceptual influences, the operation of these (local or intrinsic to visual system) "assumptions" does not amount to a top–down penetration by thoughts/cognitions or assumptions or inferences.

At the third global recurrent processing stage (around 150–200 ms), the information transmission from (non-local to visual) areas such as the frontal cortex is considered to modulate visual cortex leading to an information transfer between online visual representations and the long-term memory. This stage is considered as the late-vision (contra early-vision that comprises the above mentioned first two stages) [Pylyshyn, 1999]. Although some of the opponents of cognitive penetrability like Pylyshyn construe late-vision to be cognitively penetrable (while the early-vision is impenetrable), other opponents of penetrability like Firestone and Scholl (2016) argue that even the late-vision is impenetrable as there is no strong behavioral or phenomenological evidence, or experimental demonstration of a perceptual change due to top–down cognitive penetration; even when there are, the purported phenomenological and experimental demonstrations of cognitive penetration are indeed resultants of experimental artifacts or pitfalls rather than genuine psychological processes.

Irrespective of the controversy of the early versus late vision, the operations of downward projections, in general, can be given a non-penetration interpretation, for instance, as merely mediating (non-perceptual effects like) attention (Firestone and Scholl, 2016; Raftopoulos and Lupyan, 2018). Pylyshyn (1999) proposed the prerequisite of "semantic coherence" (i.e., a requirement of logical or rational relation between cognition and corresponding perception) to define cognitive penetration and to distinguish it from other top–down influences on perception like attentional effects. Pylyshyn (1999) says that a top–down effect will be an instance of penetration if the function that "vision computes is sensitive, in a semantically coherent way" (p. 343) to the corresponding cognition or belief, etc., top–down factors. If one perceives a banana to be red because of the thought of redness, then it can be said to be an instance of cognitive penetration as the perception (of banana to be red) is semantically coherent to the top–down thought of redness. However, if these effects occur due to those factors like attention, then it is not a case of penetration as there is no semantic coherence between the attentional state and the ensuing perceptual content.

Typically the cognitive penetrability hypothesis is tested by observing whether the cognitive or conceptual natured independent variable has any causal influence on the perceptual dependent variable. In a sense, any independent variable can be called a top–down influence but the connotation of penetration is reserved for that top–down effect that influences at the core i.e., at the central processing level of the sensory system rather than at the (peripheral) level of input or the (post-perceptual) output processes (Firestone and Scholl, 2016). For example, closing of the eyes can influence perception, but it is not considered as an instance of cognitive penetration (although it is a top–down influence over perception) because of it being an indirect effect i.e., it influences at the level of input (to vision) rather than at the level of the central-processing stage of vision. Likewise, the effects of attention are also considered to occur over input level of perception rather than at the sensory processing level itself (Raftopoulos, 2017). Although frequently one fails to perceive if she had not paid attention; however, attention, when paid, does not change the content or phenomenology of a perceptual outcome. Attention influences perception through its selectivity and amplification function, but it does not by itself accomplish perceptual (in)accuracy (Raftopoulos, 2017) or semantic (in)coherence (Gross, 2017; Pylyshyn, 1999). For instance, consider the popular cases of (illusions or) perception of ambiguous images called the Duck–Rabbit, Old/Young Woman, the Necker cube, and the Schroeder staircase, etc. In these images, the perceptions change according to the location where the perceiver looks/attends — for instance, in the case of Duck–Rabbit figure, if one looks at one end the image looks like a rabbit, and shifting attention to the other end causes the perceiver to "see" a duck. These perceptual changes are not due to changes in the sensory processing level itself, but are due to shifts of attention, i.e., due to changes at the level of input to perceptual system. So, the attentional effects are comparable to those indirect effects on perception, such as closing the eyes, which are theoretically trivial to represent cognitive penetration (Firestone and Scholl, 2016). Thus, the hypothesis of cognitive penetration — that hinges on the proposals of the cognitive scaling of perception as well as the downward neural projections into the visual system — comes under a theoretical critique.

Furthermore, there are contradictory findings in the cognitive penetration literature; for instance, some experiments — that were using the stimuli of brightness (Rima, Poujade, Maniglia, and Durand, 2018), shades of colour (Gatzia, 2017; Webster and Kay, 2012; Wright, Davies, and Franklin, 2015), distance (Abrams and Weidler, 2015; Bloesch et al., 2012; Cole and Balcetis, 2013; Hajnal, Bunch, and Kelty–Stephen, 2014; Hutchison and Loomis, 2006; Shaffer, Greer, and Schaffer, 2019), height (Huynh, Stefanucci, and Aspinwall, 2014), motion (Valsecchi, Vescovi, and Turatto, 2010), size (Collier and Lawson, 2017a, 2017b, 2018, 2019; Kirsch, Königstein, and Kunde, 2014), slant (Shaffer, Greer, and Schaffer, 2019; Shaffer, McManama, Swank, and Durgin, 2013), weight (Buckingham and MacDonald, 2015; Dijker, 2008) — found seemingly contradictory underestimations or overestimations of those stimuli that are not characteristic of the typical findings in cognitive penetration experiments.[2] These contradictory findings — as well as theoretical controversies surrounding the proposals of cognitive-scaling (e.g., Firestone, 2013) and downward neural projections (e.g., Raftopoulos, 2015) — motivate a skeptic to critically analyze the experimental evidence that purportedly establishes cognitive penetrability.

I conjecture that these contradictory reports are due to response biases rather than perceptual effects, as percepts do not contradict (from time to time) as long as there is no change in either the external stimulus or the sensory machinery.

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[2] Similarly, in the case of memory–colour effect "some of the classic experiments in the past found consistent memory–colour effects (e.g., Delk and Fillenbaum, 1965; Duncker, 1939), and some did not (in particular, see Bolles et al., 1959; Bruner et al., 1951; Fisher et al., 1956; Leibovich and Paolera, 1970; Pérez–Carpinell et al., 1998)" [Witzel and Hansen, 2015, p. 652].

I attribute these response biases to the fuzziness associated with the magnitudinal stimuli that are being used (extensively) in the cognitive penetration research paradigms. It has to be noted that most of the experiments of cognitive penetration employed magnitudinal stimuli such as brightness, distance, height, motion, orientation, shades of colour, size, slant, speed, weight as the perceptual stimuli (and magnitude estimation of which is the operationalized measure of perception).* The proponents of cognitive penetration justify the use of magnitude estimations as a legitimate measure of perception; for instance, Philbeck and Witt (2015) state that the evidence for cognitive penetration "comes from studies that use commonly-accepted methods for studying perception such as magnitude estimation (e.g., verbal reports and blind walking) and psychophysics. These have been interpreted as valid measures of perception in many studies" (p. 1123), and these "Effects have also been reported in a variety of dimensions including estimates of size, distance, slant, height, shape, speed, and weight" (p. 1130). However, although typical (subjective) magnitude estimation is proportional to the objective magnitude of the stimulus (as predicted by Stevens's power law of psychophysics), it is not veridical to the objective magnitude i.e., typical magnitude estimations are always either overestimations or underestimations.[3] The tendency of magnitude estimations to be non-veridical — as either overestimations or underestimations — can be explained by the concept of "the interval of uncertainty," i.e., "The range of the stimulus dimension over which an observer cannot perceive a difference between the comparison and the standard stimuli" (Gescheider, 1997, p. 398).[4] As already established in psychophysics, the typical estimation of magnitude is coarse-grained or fuzzy i.e., for example, magnitudes of 90, 100, 110, etc. units are perceived to be of the same magnitude. The interval-of-uncertainty of a magnitude of 100 units, for example, falls in the range between 90 units and 110 units. Because of the fuzziness (or the interval of uncertainty) of the magnitudes, the typical magnitude estimation is non-veridical — i.e., it is either overestimation or underestimation (compared to that of the objective magnitude);[5] for example, for the objective magnitudes of 90 units and 160 units, the participants usually estimate subjective magnitudes to be 100 units (i.e., an overestimation) and 150 units (i.e., an underestimation), respectively.

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[3] Typical (non-veridical) estimations of magnitude are demonstrated as the regression effect, the range effect, and the sequential or order effect. Petzschner, Glasauer, and Stephan (2015) state that the regression effect is the "tendency of subjective estimates to be biased towards the center of the distribution" (p. 286), range effect is "an increase of this bias for larger sample ranges" (p. 286), and sequential or order effects are the "correlations between subsequent magnitude judgments" (p. 286).

[4] Mathematically stated, the range of interval of uncertainty is two JNDs i.e., the interval of uncertainty = upper limen − lower limen.

[5] This non-veridical magnitude estimation is represented by the (psychophysical) notion of the "constant error." The constant error is "a stimulus value equal to the value of the point of subjective equality minus the value of the standard stimulus" (Gescheider, 1997, p. 394).

These non-veridical estimations or approximations fail to be distinguishable whether they are perceptual effects or, confounded by decisional factors or response biases — because of the fact that the non-veridical/inaccurate reports can either be due to perceptual failures or due to response biases. It should be noted that non-veridical approximations are intrinsic to magnitude estimation and thus, are bottom–up irrespective of the influence of the top–down factors (such as the cognitive penetration). Even in the typical cognitive penetration experiments, these non-veridical overestimations or underestimations of magnitudes (that are ultimately calculated as a mean, in a block) can just be due to the skewing of wavering estimations — due to the fuzziness of magnitudes — rather than to a genuine sensory effect, as the participants can freely vary their reports in the interval-of-uncertainty range. So, it is hasty to claim (by the cognitive penetration researchers) that they found evidence for perceptual effects that are penetrated by cognitive factors, as the non-veridical reports can either be due perceptual errors or decisional errors.[6]

The Instances of Cognitive Penetration as Response Biases

In situations like fuzzy magnitude estimations, the participants estimate based on their prior (or online generated) biases.[7] For instance, in the case of shades of colour, the wavelength of the red hue ranges (approximately) from 620 to 750 nanometers and the wavelength of the orange hue ranges from (approximately) 590 to 620 nanometers. If a participant is presented with a hue, for instance, in the range of 610 to 630 nanometers, she will be fuzzy whether the colour is red or orange (although she can clearly identify, for instance, 690 nm hue to be red and 605 nm hue to be unambiguously orange); in this fuzzy situation, she is prone to either underestimate the colour to be orange or overestimate it to be red, in line with her prior or online-generated biases. That is why the middle traffic light (approximately around 595 nm which is between the yellow and orange)[8] is identified to be yellow (i.e., underestimated to be around 565–590 nm) by the Germans, and identified to be orange (i.e., overestimated to be around 600–625 nm) by the Dutch (even though the presented hue is objectively the same) [Mitterer, Horschig, Müsseler, and Majid, 2009]; and this happens merely because of the cultural practice of terming the middle traffic light's colour to be yellow

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[6] Although the cognitive penetration hypothesis is proposed to have practical implications (Krpan and Schnall, 2017; Witt, Linkenauger, and Wickens, 2016) because of the functionality of the cognitive scaling of perception, this hypothesis fails to deliver that promise (Gray, 2016; Loomis, 2016) particularly because of being an instance of response bias (under perceptual uncertainty).

[7] For instance, Witzel, Olkkonen, and Gegenfurtner (2018, p.2) agree that there occurs "more shift or bias towards the prior when uncertainty in the sensory signal increases (Knill and Richards, 1996; Maloney and Mamassian, 2009)."

[8] It is often termed as the color, amber.

(or Gelb) in Germany and orange (or Oranje) in The Netherlands — without a change in the perceptual apparatus of colour. Similarly, the cultural practice of terming a banana to be yellow makes a fuzzy greyish-yellow banana to be (over-estimated to be) yellowish (e.g., Hansen et al., 2006). However, it has to be noted that this type of memory–colour effect is not due to a change in (low-level) visual processes — in terms of changes in discrimination thresholds per se (Hansen, Giesel, and Gegenfurtner, 2008; Witzel and Hansen, 2015) — but due to (linguistic or cultural or even participant-specific online-generated) biases in the estimation of the magnitudes of fuzzy/ambiguous hues.

A similar example of the influence of prior-belief-based response bias in fuzzy magnitude estimation is that political conservatives estimate Barack Obama's skin tone to be darker than what political liberals estimate it to be (Caruso, Mead, and Balcetis, 2009). However, this is not an effect of cognitive penetration per se but a response bias that is based on (prior) partisan attitudes of conservatives and liberals, as the very same effects "obtain with unambiguously non-perceptual and even silly factors" (Firestone and Scholl, 2015a, p. 1217); for instance, conservatives report an image of Obama with red horns on his head to be more representative of him rather than an image where his head has yellow halos. If conservatives can estimate Obama's head to be horned, for non-perceptual reasons, then it is equally possible for them to estimate Obama's face to be darker, for non-perceptual reasons as well (Firestone and Scholl, 2015a). Thus, the instances of cognitive penetration in colour perception could be instances of response bias (Brogaard and Gatzia, 2017; Deroy, 2013; He et al., 2014; Mitterer et al., 2009; Valenti and Firestone, 2019; Zeimbekis, 2013), particularly those that result due to the fuzziness of the magnitude of a colour.[9]

Similarly, in the case of spatial perception, fuzziness associated with the magnitude of orientation or slant can lead to either its overestimation or underestimation (irrespective of any top–down penetration).[10] When the orientation of the slant of a scene is fuzzy — due to the lack of information about visual reference cues such as the true horizontal — overestimations of slant occur, typically about 6° (Daum and Hecht, 2018; Ross, 1974), and a slant between 7° and 10° is overestimated to be around 30° (Durgin and Li, 2017). Durgin and Li (2017) attribute the overestimations of slant to people's tendency to misperceive their gaze direction; for instance, an outdoor path on a hill that has an objective slant of 5° is estimated

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[9] This conclusion is further substantiated by the evidence that colour language and colour perception are not necessarily correlated (Brown, Lindsey and Guckes, 2011; Davies, 2018; Emery, Volbrecht, Peterzell, and Webster, 2017; Siuda–Krzywicka and Bartolomeo, 2020; Siuda–Krzywicka et al., 2020) raising scepticism over the possibility that colour language penetrates colour perception at all, because, if colour language penetrates colour perception then colour language should at least correlate with colour perception.

[10] For instance, Daum and Hecht (2018) agree that the slant perception is "inherently shaky as soon as the slope in question is no longer palpable, that is if it is outside our personal space" (p. 183).

to be around 20° whether the observer viewed it from the top or the bottom (Proffitt, Bhalla, Gossweiler, and Midgett, 1995). The overestimation of the slant of an entity is further escalated by the increasing distance of that entity from the observer (Hecht, Shaffer, Keshavarz, and Flint, 2014). The slant overestimation is attributed to the intrinsic tendency of the visual system that occurs independently of cognitive penetration. For instance, Durgin and Li (2017) attribute slant overestimations to our evolutionary adaptation to gravity, by stating that "these biases seem to be coded primarily with respect to the extrinsic reference frame specified by gravity (Durgin et al., 2010b). … Because slant is defined relative to a gravitational reference frame (i.e., the horizontal plane and the vertical vector of gravity that is normal to horizontal), errors in perceived slant could come about if the presence of a hill produced a distortion in the perception of the horizontal plane" (pp. 193–194). Thus, the instances, of cognitive penetration in slant perception could be response biases (Bang and Rahnev, 2017; Dean et al., 2016; Durgin, 2017; Durgin et al., 2009; Durgin, Klein, Spiegel, Strawser, and Williams, 2012; Durgin, Ruff, and Russell, 2012; Firestone, 2013), particularly due to the fuzziness associated with the magnitude of slant. Similarly, there is evidence that the instances of cognitive penetration in the reports of distance (Woods, Philbeck, and Danoff, 2009) and size (Briscoe, 2014; Collier and Lawson, 2017a, 2017b; Cooper, Sterling, Bacon, and Bridgeman, 2012; Wesp and Gasper, 2012; Zelaznik and Forney, 2016) could be instances of response bias.

Furthermore, post-experiment debriefing sessions by some researchers found that the experimental instances of cognitive penetration are indeed due to response biases, as the participants guessed the experimental hypothesis and responded accordingly. For instance, participants who are estimating slopes (under the influence of bioenergetic factors such as wearing a heavy backpack) report that "I think I was asked to wear the backpack because when a person judges the slope of a hill their judgment can be skewed based on how difficult they think climbing the hill will be" (Durgin, Klein et al., 2012, p. 1594).[11] If the purported cognitive penetration effects are due to the use of the magnitudinal stimuli that are fuzzy, then it is possible that controlling for fuzziness — for instance, by employing categorical stimuli — will eliminate the typical cognitive-penetration-like effects.

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[11] Sometimes, the participants can guess the hypothesis due to the recruitment process; for instance, Philbeck and Witt (2015, p. 1131) agree that "several studies involving athletes collected perceptual judgments before assessing performance, but participants were aware that recruitment took place at softball fields and golf courses (Witt and Proffitt, 2005; Witt et al., 2008). Thus, this may have made the hypothesized importance of their athletic ability salient. As another example, recruiting younger and older adults at an assisted living facility (Sugovic and Witt, 2013) likely made age a salient factor, and recruiting patients and employees at a chronic pain clinic (Witt et al., 2009) likely made pain a salient factor. In contrast, recruiting adults at a public shopping center and measuring their weight and BMI after collecting all perceptual measures is an effective way to conceal an interest in body size (Sugovic and Witt, 2011)."

No Cognitive Penetration under Categorical Operationalization of Perception

The perceptual fuzziness can be controlled if the perception is operationalized as a category identification task; the categorical stimuli, such as the category of orange and the category of yellow avoid being fuzzy by virtue of falling beyond the zone of "interval of uncertainty" of the border-zone of yellow and orange i.e., between 585 nm to 605 nm, approximately. If categorical perceptual stimuli — such as unambiguously yellow or unambiguously orange — are employed in the cognitive penetration experimental-paradigms then the participants do not resort to response biases (that usually occur under perceptual fuzziness). So, in the cognitive penetration research, instead of asking the participants "how yellowish is the banana," "how reddish is the heart," or "how orangish is the middle traffic light," the experimenter can ask the participant (to identify the category of the stimuli by asking) "what is the colour of the banana seen — grey or yellow?," "what is the colour of the heart seen — orange or red?," or "what is the colour of the middle traffic light seen — yellow or orange?"; or the experimenter can alternatively instruct the participant to compare and match the grey banana to a reference grey-category hue or a reference yellow-category hue, or match the orange heart to a comparable orange-category hue or a red-category hue, or match a yellow middle-traffic-light to a yellow-category hue or an orange-category hue.[12]

In this sort of categorical operationalization of perception typical cognitive-penetration-like effects might not be observed i.e., the participants are likely to report a grey banana to be similar in colour to a grey hue rather than to a yellow hue, an orange heart to be similar in colour to an orange hue rather than to a red hue, and a yellow traffic light to be of the colour yellow rather than of the colour orange, irrespective of any influence of penetration by memory–colour (Valenti and Firestone, 2019); if perception is operationalized as an activity of category identification then there will not be any differences in the (veridical) perceptual reports between the experimental group and the control group, as the participants are not fuzzy or ambiguous about the category of the perceived stimuli, and they do not resort to non-veridical perceptual reports such as overestimation or underestimation (that are characteristic of the magnitude estimation). So, the instances of cognitive penetration could merely be instances of experimental confounding due to the fuzziness of the magnitudinal stimuli.

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[12] See a figure of representative stimuli at https://doi.org/10.6084/m9.figshare.14345141.v1 where the color perception is operationalized as a comparison and matching (or a discrimination) between the categories of colours; also see Figure 3 of Valenti and Firestone, 2019 for a similar (discrimination/odd-one-out) kind of operationalization of colour perception.

Cognitive Penetration through Categorical Stimuli as a Bottom–Up Effect

Although the cognitive penetration research has predominantly operationalized perception to be a magnitude estimation, some experiments (on rare occasions) employed categorical stimuli such as faces (e.g., Levin and Banaji, 2006), binocular rivalry (e.g., Anderson, Siegel, and Barrett, 2011; Antinori, Carter, and Smillie, 2017; Balcetis, Dunning, and Granot, 2012; Klink, van Wezel, and van Ee, 2012; Scocchia, Valsecchi, and Triesch, 2014; Weng et al., 2019; Wilbertz, van Slooten, and Sterzer, 2014), illusions (e.g., Lupyan, 2015; Topolinski, Erle, and Reber, 2015; van Ulzen, Semin, Oudejans, and Beek, 2008; Vishton et al., 2007), ambiguous images and objects (e.g., Balcetis and Dunning, 2006; Dunning and Balcetis, 2013; Lupyan, 2012; Lupyan, Thompson–Schill, and Swingley, 2010; Lupyan, and Ward, 2013), and ambiguous words (e.g., Lupyan, 2017; Lupyan et al., 2010). However, these cases of cognitive penetration, even when they are employing categorical stimuli, can be due to bottom–up stimulus-related-factors rather than due to top–down penetration per se.

For instance, the penetration-like effect in face perception can be bottom–up (due to the use of those face-stimuli that are prone to confounding by bottom–up stimulus features). The face–race lightness effect (Levin and Banaji, 2006) — where a face-stimulus of a Black person looks darker compared to that of a White person even though both of the faces have equal average luminance — is being proposed as an example of cognitive penetration that operationalized categorical perceptual stimuli (see Figure 2 of Levin and Banaji, 2006 for the representative face-stimuli used in the face-race lightness effect). However, a (stimulus-specific) bottom–up explanation for the face–race lightness effect can be offered instead of penetration by the knowledge of the race in face perception — as some regions of the Black face and White face were (confoundedly) allowed to have differences in darkness and lightness.[13] For instance, Firestone and Scholl (2016) point out that "the Black face seems to be under illumination, whereas the White face doesn't look particularly illuminated or shiny.… And the Black face has a darker jawline, whereas the White face has darker eyes" (p. 12).

The bottom–up differences in face–race stimuli will lead to differences in the subjective perception of face lightness via "simultaneous contrast," the tendency of human lightness perception where a perceived colour is influenced by surrounding colour or illumination (Adelson, 2000). For instance, in the Checker–Shadow illusion (Adelson, 2000), which is an example–demonstration of the phenomenon of simultaneous contrast, the target squares or tiles are of the same hue; however, they are perceived to be of different shades of grey because of the lightness or darkness of the surround in which these target squares are located.

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[13] The intention of the researchers to allow for differences in terms of darkness and lightness between the Black face and White face is to achieve identical average luminance between them (Bitter, 2014).

This is a bottom–up effect — intrinsic or local to the visual system — that could be attributable to the tendency of lightness constancy, which is an evolutionary adaptation for perception in daylight illumination and shadowing (Sinha et al., 2020; Winkler, Spillmann, Werner, and Webster, 2015; Witzel and Gegenfurtner, 2018). The simultaneous contrast effect that accounts for the face–race lightness effect (as well as checker–shadow illusion) is the product of on-centre and off-surround process (or lateral inhibition process) in the receptive field of the retina (Rizzi and Bonanomi, 2017). The bottom–up explanation for the face–race lightness effect can be further substantiated by the finding that "Observers who viewed heavily blurred versions of the original Black and White faces still judged the Black face to be darker and the White face to be lighter even when these observers could not perceive the races of the faces, and even when they explicitly judged the faces to be of the same race" (Firestone and Scholl, 2015b, p. 694).

Furthermore, one more bottom–up factor that amplifies the face–race lightness effect is attention (albeit as an effect on the input-level of vision rather than on the central-processing-level of vision per se). For instance, it is being found that eye fixations over a Black face-stimulus and a White face-stimulus differ: brighter regions of the Black face-stimulus captivate longer gaze fixations over that of a White face-stimulus, and a Black face-stimulus elicits comparatively smaller mean pupil diameters than that of the White face-stimulus (Laeng et al., 2018); further, it is also being found that by curtailing eye fixations over locally brighter or darker regions of face–race stimuli — by presenting those stimuli very quickly (tachistoscopically, in 140 ms) — the typical face–race–lightness tendency to report the Black face-stimulus as "dark" is eliminated (Laeng et al., 2018). Further corroboration for the interpretation that the face–race lightness effect is indeed an attentional effect comes from the fact that the region around the nose (Hsiao and Cottrell, 2008; Peterson and Eckstein, 2012) or eyes (Thompson, Foulsham, Leekam, and Jones, 2019; Vinette, Gosselin, and Schyns, 2004) — i.e., the eye–mouth triangle — is preferentially (gaze) attended over any other part of the (static) face (Arizpe, Walsh, Yovel, and Baker, 2017);[14] thus, the nose region of the face–race–lightness stimuli acts as the centre and all other parts of the face act as the background or surround — with a contrast in illumination from that of the centre — in giving rise to the simultaneous contrast effect. Here, the Black face-stimulus is seen as the light eye–mouth triangle in the background of darker edge-regions of the face.

Similarly, the purported instances of cognitive penetration in binocular rivalry — the perceptual phenomenon with characteristic perceptual alternations between the two dissimilar stimuli (presented to the two eyes individually) and perceptual dominance (that alternates between the two stimuli) — can be argued

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[14] The preferential (gaze) attending at the eye–mouth triangle could be an evolved adaptation to perceive emotions in facial expressions (Bombari et al., 2013; Calvo, Fernández–Martín, Gutiérrez–García, and Lundqvist, 2018; Schurgin et al., 2014)

to be an instance of bottom–up effect — i.e., as a function of both the eye as well as the stimulus (Blake and Logothetis, 2002; Tong, Meng, and Blake, 2006; Ward and Scholl, 2015) — rather than an instance of top–down penetration. For instance, interocular differences — in terms of the stimulus dimensions such as colour, luminance, contrast polarity, orientation, form, size, or velocity etc. — in the images presented to left eye and right eye (Blake and Tong, 2008) as well as the intrinsic tendency — the adapting reciprocal inhibition — of the neurons of the visual system (Alais and Blake, 2015) can account for the characteristic perceptual dominance and alternations of binocular rivalry. Thus, the seemingly top–down effects in binocular rivalry could be due to physiological principles — such as those behind Gestalt perceptual organization — that are intrinsic to the visual system itself (Brascamp, Klink, and Levelt, 2015; Dobbins and Grossmann, 2010; Girshick, Landy, and Simoncelli, 2011; Zhang, Xu, Jiang, and Wang, 2017). Furthermore, binocular rivalry occurs only when two monocular stimuli presented to two eyes are too different to be integrated into one stereoscopic appearance (of the typical 3D world). Thus, binocular rivalry can be likened to be a case of more general bistable (or multistable) stimuli such as the Necker cube and the Rubin face/vase illusion etc. (Brascamp and Baker, 2013), where there occurs a conflict between different perceptually incompatible images or stimuli, which, however, are individually visually self-sufficient percepts. As the perceptual alternations of bistable stimuli are attentional effects (Hsiao, Chen, Spence, and Yeh, 2012), the perceptual dynamics of binocular rivalry can also be attributed to (exogenous as well as endogenous) attention (Chong and Blake, 2006; Dieter, Melnick, and Tadin, 2015; Hancock and Andrews, 2007; Li et al., 2017; Mishra and Hillyard, 2009). As the attention effects actually occur at the level of input to the visual system rather than at the level of (central) processing of the visual system, the top–down-like influences on binocular rivalry are not instances of cognitive penetration.

Similarly, penetration-like effects in illusions can be interpreted to be bottom–up effects, as visual illusions are the byproducts of neural processes that are involved in perceptual organization, such as transforming 2D information on the retina to a 3D perceptual image and achieving constancies of shape and size by using monocular/binocular depth or distance cues (by employing inappropriate constancy scaling or misapplied constancy scaling) [Ninio, 2014]. Although visual illusions deviate from the stimulus-information they are intrinsic [and specific (Cretenoud et al., 2019)] to visual neural processes; for instance, inappropriate constancy scaling with respect to depth — that hinges on the corners and converging lines of the Müller–Lyer stimulus — explains the Müller–Lyer illusion (Gregory, 1963; Ward, Porac, Coren, and Girgus, 1977). The claim that the inappropriate constancy scaling is intrinsic to the visual system (and is independent of top–down penetration) is further substantiated by the observation that the newly-sighted congenitally blind children still experience illusions like the Müller–Lyer illusion

(Gandhi, Kalia, Ganesh, and Sinha, 2015). So, the typical cognitive penetration findings while using visual-illusion stimuli can be a bottom–up effect.

Furthermore, the subjective reports over ambiguous images or ambiguous objects could be due to response bias, because of the very fact that the images are ambiguous, and thus, elicit heuristic biases under uncertain/ambiguous conditions (see Zeimbekis, 2015 for a similar interpretation of the claims of cognitive penetration in the perception of ambiguous images or objects). Thus, although some of the cognitive penetration experimental paradigms have used categorical stimuli (such as ambiguous images, binocular rivalry and face–race lightness stimuli), it can be argued that the perceptual reports in these paradigms are indeed bottom–up effects rather than due to top–down penetration per se. If unambiguous categorical stimuli were used (as discussed early in this section) then there might not have been any experimental observation of typical cognitive-penetration-like effects — as the participants might not resort to non-veridical estimations or approximations that usually occur due to fuzzy magnitudinal stimuli.

Behavioural (Instead of Verbal Report) Measures of Cognitive Penetration

Some cognitive penetration paradigms used behavioural measures to study perceptual effects hoping to keep a check over response biases associated with verbal reports of perception. For instance, it is being reported that non-sensory factors such as bodily states and emotions (Anderson, Siegel, Bliss–Moreau, and Barrett, 2011; Correll, Wittenbrink, Crawford, and Sadler, 2015; Radel, and Clément–Guillotin, 2012), language (Boutonnet and Lupyan, 2015; Lupyan and Spivey, 2010; Lupyan and Swingley, 2012; Lupyan and Ward, 2013; Maier and Abdel Rahman, 2018), and conceptual/semantic knowledge or beliefs (Gantman and Van Bavel, 2014; Weller, Rabovsky, and Abdel Rahman, 2019; Zacharopoulos, Binetti, Walsh, and Kanai, 2014) lead to "enhanced perceptual sensitivity" or "ease of perceptual processing." Similarly, non-sensory factors like conceptual knowledge and memory (Lupyan et al., 2010; Thierry et al., 2009; Witzel and Gegenfurtner, 2015; Witzel, Valkova, Hansen, and Gegenfurtner, 2011) leads to "quicker RTs" of perceptual processing. Other behavioural measures (of perception) include the "distance of space blind-walked" (e.g., Witt, Proffitt, and Epstein, 2010) and "distance of space a bean bag or a ball is thrown" (e.g., Linkenauger, Bülthoff, and Mohler, 2015).

However, the behavioural measures used in cognitive penetration research are debatable whether they are perceptual effects at all. For instance, Philbeck and Witt (2015) agree that behavioural measures are possible "in ways that have nothing to do with the underlying perceptual representation. For example, if action capability were manipulated by asking participants to throw a pencil versus an anvil at a target, the pencil could be thrown farther, but it would be a mistake to attribute this result purely to differences in perceived target distance" (p. 1123). This is further substantiated by dissociation or non-correlation observed between the behavioural and the verbal measures.[15] For instance, the verbal estimations of slant are not correlated with the behavioural measures of slant perception (Eves, 2015; Proffitt and Zadra, 2011); even when there is a correlation between verbal and behavioural measures of slant perception, this correlation is still attributable to response biases rather than to cognitive penetration per se (Durgin et al., 2010; Shaffer et al., 2014). Similarly, verbal estimations of distance are not correlated with behavioural measures of distance (Paterson, van der Kamp, Bressan, and Savelsbergh, 2019); even if there are correlations between verbal and behavioural measures of distance perception (Loomis and Philbeck, 2008; Tenhundfeld and Witt, 2017) they are can be attributed to decisional factors or response biases (Durgin et al., 2011).

Although the behavioural measures are hypothesized to avoid the pitfalls that arise when using verbal report measures (Philbeck and Witt, 2015; Witt, Sugovic, Tenhundfeld, and King, 2016), behavioral measures still fail to distinguish whether the measured behavior is a perceptual effect or a response bias, particularly when the measured behaviour is non-veridical — a similar predicament to that of the fuzzy magnitude estimation. That is why there are contradictory overestimations and underestimations even in the "behavioural measures of perception"; for instance, the measure of throwing a heavy ball "sometimes produces significant effects on estimated distance (Witt et al., 2004) and sometimes does not (Woods et al., 2009)" [Philbeck and Witt, 2015, p. 1132]. Accordingly, some findings suggest that the behavioural measures like ball throwing and blind-walking can be instances of response biases (Durgin et al., 2009; Woods, Philbeck, and Danoff, 2009) where, for instance, a ball is thrown not based on perceived distance but remembered distance (Cooper et al., 2012), and where, for instance, a ball is thrown or a distance is blind-walked not because of perceived distance but due to planned or prepared action (Firestone, 2013). Similarly, it is being argued that (behavioural measures such as) enhanced sensitivity or ease of perceptual processing (Firestone and Scholl, 2015c; IJzerman, Regenberg, Saddlemyer, and Koole, 2015) and quicker RTs (Reuther and Chakravarthi, 2017; Fernández and Vadillo, 2020) in the context of cognitive penetration can be due to non-sensory or decisional factors. Thus, the purported instances of cognitive penetration that operationalized either verbal reports or behavioral measures are mere instances of response biases.

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[15] For instance, Philbeck and Witt (2015, p. 1123) argue that the behavioural measures "that involve online visual control of rapid, precise movements, are thought to be guided by visual information processed in a dorsal cortical pathway that is anatomically and functionally distinct from a ventral pathway that presumably subserves conscious visual perception (Milner and Goodale, 1995)."

Conclusion

The manifestation of cognitive penetration can be argued to be an instance of experimental confounding by extraneous variables — such as a response bias in the context of fuzzy magnitudinal stimuli — and thus, is not a perceptual effect per se. Moreover, had the confounding by fuzzy magnitudinal stimuli been controlled for by employing categorical stimuli, then the typical cognitive-penetration-like effects might not have been observed at all. Furthermore, the behavioral measures of perception also fail to establish that cognitive penetration is not an instance of response bias. Thus, it can be concluded that the purported instances of cognitive penetration are mere instances of experimental confounding by extraneous variables (but not due to the cognitive scaling of perception or due to the influence of downward neural projections per se), raising scepticism over the very validity of the construct.

Endnote

* Below are the sample research works in cognitive penetration that used magnitudinal stimuli as the dependent variables: the perception of "brightness" is shown to be penetrated by emotions (Meier, Robinson, Crawford, and Ahlvers, 2007) and moral thoughts (Banerjee, Chatterjee, and Sinha, 2012); the perception of "distance" is shown to be penetrated by motor action (Kirsch and Kunde, 2013, 2015; Witt and Proffitt, 2008), age (Sugovic and Witt, 2013), emotion (Cole, Balcetis, and Dunning, 2013), bioenergetics state (Sugovic, Turk, and Witt, 2016; Zadra, Weltman, and Proffitt, 2016), motivation (Balcetis, 2016; Cole, Balcetis, and Zhang, 2013; Krpan and Schnall, 2014a, 2018), physical effort (Vinson, Jordan, and Hund, 2017; White, Shockley, and Riley, 2013; Witt, Proffitt, and Epstein, 2010), and psychological effort (Cole and Balcetis, 2013; Slepian, Masicampo, and Ambady, 2014); the perception of "height" is found to be penetrated by motor action (Taylor, Witt, and Sugovic, 2011), and emotion (Harber, Yeung, and Iacovelli, 2011; Storbeck and Stefanucci, 2014); some experiments found that the perception of "motion" is penetrated by action (Kawabe, 2013; Wallis and Backus, 2016), language (Dils and Boroditsky, 2010; Francken, Kok, Hagoort, and De Lange, 2015; Meteyard, Bahrami, and Vigliocco, 2007), and semantic knowledge (Hsu, Taylor, and Pratt, 2015; Kim, Feldman, and Singh, 2013); the perception of "orientation" is found to be penetrated by action (Kirsch and Kunde, 2014), emotion (Bocanegra and Zeelenberg, 2009; Phelps, Ling, and Carrasco, 2006), and language (Kranjec, Lupyan, and Chatterjee, 2014; Pelekanos and Moutoussis, 2011); the perception of a "shade of a color" is found to be penetrated by the modalities of memory (Hansen, Olkkonen, Walter, and Gegenfurtner, 2006; Lee and Mather, 2019; Lupyan, 2015; Olkkonen, Hansen, and Gegenfurtner, 2008), language (Thierry et al., 2009; Zheng et al., 2017), and motivation (Caruso, Mead, and Balcetis, 2009; Krosch, and Amodio, 2014); the perception of "size" is found to be penetrated by motor action (Franchak, van der Zalm, and Adolph, 2010; Kirsch, Herbort, Ullrich, and Kunde, 2017; Linkenauger, Witt, and Proffitt, 2011; Witt, 2011), body ownership (Banakou, Groten, and Slater, 2013; Linkenauger, Leyrer, Bülthoff, and Mohler, 2013; Linkenauger, Ramenzoni, and Proffitt, 2010; Van der Hoort and Ehrsson, 2014), culture (Davidoff, Fonteneau, and Goldstein, 2008), emotion (Leibovich, Cohen, and Henik, 2016; Morgado, Muller, Gentaz, and Palluel–Germain, 2011; Stefanucci, Gagnon, Tompkins, and Bullock, 2012; van Ulzen, Semin, Oudejans, and Beek, 2008), motivation (Daas, Häfner, and Wit, 2013; Van Koningsbruggen, Stroebe, and Aarts, 2011), and performance efficacy (Cañal–Bruland, Pijpers, and Oudejans, 2012; Gray, 2013; Jin and Lee, 2013; Lee, Lee, Carello, and Turvey, 2012; Witt, Linkenauger, Bakdash, and Proffitt, 2008); the perception of "slant" is being found to be penetrated by emotion (Riener, Stefanucci, Proffitt, and Clore, 2011; Zadra and Clore, 2011), bodily glucose level (Krpan and Schnall, 2017; Schnall, Zadra and Proffitt, 2010; Taylor–Covill and Eves, 2014), physical effort (Burrow, Hill, and Sumner, 2016; Krpan and Schnall, 2014b; Taylor-Covill and Eves, 2013), and psychological effort (Slepian, Camp, and Masicampo, 2015; Zheng et

al., 2015); the perception of "speed" is found to be penetrated by action (Witt, 2020), emotion (Witt and Sugovic, 2013), and performance efficacy (Witt and Sugovic, 2010, 2012; Witt, Tenhundfeld, and Bielak, 2017); and the perception of "weight" is found to be penetrated by emotion (Min and Choi, 2016), one's hand size (Linkenauger, Mohler, and Proffitt, 2011), performance efficacy (Lee and Schnall, 2014), and psychological effort (Doerrfeld, Sebanz, and Shiffrar, 2012).

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