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Functional and Temporal Considerations for Top-Down Influences in Social Perception

Ryan M. Stolier and Jonathan B. Freeman

Department of Psychology, New York University, New York, New York

Perception has long been presumed to play an integral role in social cognition and subsequent behavior. Our inferences, judgments, and actions toward a person are of course driven by how we perceive that person. In light of developing views on the bidirectional interplay of cognitive and perceptual processes (Gilbert & Li, 2013), recent theory in social psychology has expanded and refined older theory (Bruner, 1957) to account for how top-down social processes, such as motivations and stereotypes, influence perceptual processing and its consequences (Adams, Ambady, Nakayama, & Shimojo, 2011; Balcetis & Lassiter, 2010; Stolier & Freeman, 2016a). Y. Jenny Xiao, Géraldine Coppin, and Jay J. Van Bavel (this issue) apply these advances to develop a model of intergroup relations through which top-down group-level processes, such as social identity and context, influence intergroup behavior through their impact on perception. For instance, resource allocation to racial outgroup members is influenced by the prototypicality of visual representations of their race (Krosch & Amodio, 2014).

This model is the first to emphasize the meditational role of socially malleable perceptions upon intergroup relations. Xiao et al. emphasize that certain intergroup behaviors may be uniquely exacerbated by top-down modulated perceptions, such as resource scarcity impacting resource allocation by first altering face perception (e.g., Krosch & Amodio, 2014), in ways that would not occur were these perceptual modulations lacking. That is, exaggerated outgroup perceptions (e.g., perceived "Blackness") have an influence on intergroup behavior over and above the merely cognitive biases of coalitional psychology (Sidanius & Pratto, 2001; Stephan & Stephan, 2000; Tajfel, 1974). Notably, the authors provide a broad review of observed top-down perceptual impacts that may trickle into intergroup behavior, spanning vision, audition, smell, taste, and touch. To date, the conversation concerning top-down influences in social perception has by and large focused upon vision (Adams et al., 2011; Balcetis & Lassiter, 2010). Xiao et al. bring the role of other sensory modalities to the foreground of perception, all which may play significant roles in behavior across the myriad contexts of modern intergroup interaction.

The authors importantly note that there is a dearth of research regarding the link between top-down perceptual modulations and downstream behavior (such as intergroup behavior). Although some research has begun to test this relationship (e.g., Freeman, Pauker, & Sanchez, 2016; Krosch & Amodio, 2014; Ratner, Dotsch, Wigboldus, van Knippenberg, & Amodio, 2014), one crucial consideration for this research will be to causally examine these pathways. Indeed, it is possible that these effects may be correlational in nature, and perceptual modulations by social factors may not exaggerate behavior at all, nonetheless substantially. Therefore future studies should consider not only testing this pathway but also aiming to directly manipulate the presence of top-down perceptual influences to determine their role in downstream processes such as behavior.

The aforementioned role of perception in mediating the relationship between intergroup psychology and behavior, like many recent models of social vision, by and large focuses on top-down influences on perceptual experience and judgment, for instance, shifts in the perception of a face's pigmentation (Caruso, Mead, & Balcetis, 2009; Freeman, Penner, Saperstein, Scheutz, & Ambady, 2011b; Krosch & Amodio, 2014). Although this model specifies the impact of social factors on discrete and cross-modal perceptual-processing systems (e.g., visual cortex, olfactory cortex, association cortex), it is agnostic to the functional nature and level of processing at which top-down perceptual influences occur within these systems (e.g., level of the visual processing hierarchy). Furthermore, these models are often agnostic to the temporal dynamics of top-down modulations. Indeed, much of top-down influence on visual processing is thought to occur across multiple levels of visual processing (Gilbert & Li, 2013), sometimes even only modulating a process temporarily before the process achieves a stable outcome. For instance, context may assist the speed of visual recognition of an object, such as a tool in a toolshed, without necessarily causing any stable shift in perception (Bar, 2004). In this commentary, we discuss the importance of the functional and temporal specificity of top-down effects in perceptual models of social behavior. First, we discuss the functional nature and level of processing at which these effects occur, as this largely determines the possibilities and potential for interventions. Second, we discuss the temporal dynamics of these effects, as they may lead to more psychologically and neurally plausible models of top-down social perception, and importantly uncover many instances in which these effects occur but are not observed in measures of final perceptual outcomes.

Identifying and Integrating Mechanisms

Although discussed briefly by Xiao et al. (this issue), psychological models of top-down influences in social perception have to this point remained largely agnostic to the nature and level of processing at which modulations occur. The nature and level of these modulations may speak substantially to their

CONTACT Ryan M. Stolier rystoli@nyu.edu Department of Psychology, New York University, 6 Washington Place, New York, NY 10003, USA.

susceptibility to various interventions. For instance, a group influence on visual attention may demand different intervention techniques than an influence upon visual experience per se. Here we briefly review knowledge of top-down mechanisms from cognitive neuroscience and discuss their unique implications for the process and intervention of intergroup perceptual biases.

Perceptual processing is a vastly complicated process, through which hierarchically complex representations feed forward and assist backwards to achieve a stable perceptual state (Gilbert & Li, 2013; Grill-Spector & Weiner, 2014). Our most intricate knowledge of these processes comes from vision science, where neural systems involved have been extensively mapped functionally and anatomically. From visual neuroscience, we know that receptive fields initially tuned to line orientations build forward along ventral temporal cortex into successively complex and holistic representations of surfaces and objects in our environment, all the while providing recurrent feedback to earlier visual regions to assist processing (Grill-Spector & Weiner, 2014).

One important specification regarding top-down effects is that feedback from higher order cognitive regions does not necessarily extend to all perceptual levels equally, much less at all. The lack of feedback between certain regions may speak to the degree or plausibility of top-down influences on perceptual experience as opposed to processing or attention (though this relationship is, of course, complicated; Summerfield & Egner, 2009), or interpretation and judgment. For example, specific projections have been identified from the amygdala (to V1 and area TE; Freese & Amaral, 2005), orbitofrontal cortex (OFC; predominantly lateral OFC and some medial OFC to unimodal perceptual regions; Barrett & Bar, 2009), and prefrontal cortex (to areas such as V2; Zanto, Rubens, Thangavel, & Gazzaley, 2011). In addition, higher order regions may project back through cascading signals via points such as the thalamus (Gilbert & Li, 2013). As we come to better map these pathways, we may begin to constrain our models of top-down perceptual effects.

Furthermore, identifying where in the processing stream top-down modulations occur may speak to process. For instance, consider shifts in racial hypodescent related to political orientation (Krosch, Berntsen, Amodio, Jost, & Van Bavel, 2013). In this research, it was found that the threshold for Black categorization of racially ambiguous faces was lower for more politically conservative participants. One commonly recurring question in such studies investigating top-down effects is whether this reflects a bias in judgment or whether ambiguous faces are actually visually experienced as having more Afrocentric features (i.e., an effect on featural representation), resulting in a shifted categorization. Recently, Brouwer and Heeger (2013) found that monotonically graded color representations cluster together in line with their psychologically perceived categories in certain cortical regions involved in color perception (V4, VO1), suggesting that top-down knowledge related to color categories manifests in visual processing. If researchers were to observe color or face race representations to cluster differently between subjects, in line with Krosch et al. (2013), in perceptual regions as opposed to higher order regions, it may help to distinguish the cause of this effect (e.g., perception vs. judgment), and therefore how it may be intervened upon. However, it should also be noted that while the perception vs. judgment distinction is a valuable one, it is considerably complex and these processes may not always be cleanly separable.

Another critical specification is the nature of these modulations. Top-down influences take on many forms, from shifts in attention that amplify or attenuate featural representation to predictions that tune receptive fields and ease recognition. Although spatial attention focuses on and enhances processing of specific features and stimuli in the visual field, feature oriented attention increases sensitivity to specific features across the visual field. Expectation, on the other hand, provides predictions that shift receptive fields to be ready and quickly process the expected stimulus or features (for review, see Gilbert & Li, 2013). Each of these mechanisms likely require different interventions if they influence intergroup perception and behavior. For instance, in one study, higher implicit race bias predicted an increased readiness to see anger in the faces of Black but not White targets (Hugenberg & Bodenhausen, 2003). It could be the case that this top-down effect is due to heightened spatial attention to emotion cues in Black targets (e.g., furrowed brow, teeth). Alternatively, this could be due to stereotypic expectations that facilitate the activation of the angry category and perhaps featural representation of angry cues even though anger is not objectively displayed on the face. This effect would be susceptible to markedly different interventions depending on which mechanism is at play.

One important divide between functionally specific top-down modulations is whether they occur online during perception or are learned and engrained within perceptual representations themselves. This distinction is focal in discussion of cultural differences in perception. Research has long noted the relative Western preference for analytic, object-focused attention, as opposed to the Eastern holistic, context-sensitive perception (Nisbett, Peng, Choi, & Norenzayan, 2001). Nisbett and Miyamoto (2005) discussed a variety of research observing these biases both chronically learned (through culture) and temporarily induced online (through primed social orientation). Indeed, we could consider both online and learned causes underlying cultural variation in the Mueller–Lyer illusion discussed by Xiao et al. (Segall & Campbell, 1966) or color category perception (Roberson, Davies, & Davidoff, 2000).

In one recent study, we found social category representations in the right fusiform gyrus (rFG) and OFC to be biased toward one another to the degree that they shared stereotypes (Stolier & Freeman, 2016b). For instance, the categories "Black" and "male" share a number of stereotypes (e.g., aggressive) and were subsequently observed to be more similar in multivoxel pattern representation. Theoretically, these findings are in line with the research showing that the OFC provides top-down expectations and priors that aid perceptual processing (Bar, 2004). We speculate that perception of one category, for example, "male," activates related stereotypes via the OFC, which provides priors activating the "Black" category to an extent, resulting in a "male" representation that approximates the "Black" representation more than "female" in the rFG. However, it is entirely possible that the online retrieval and interplay between the rFG and OFC is unnecessary, and through learning and chronic coactivation of these categories and stereotypes, the male and Black categories in the rFG are more permanently represented similarly. Indeed, attractor neural network models show that when two representations are learned, semantic similarity (and by extension here, similarity in stereotype contents) will lead the two neural network patterns to be more similar (e.g., Plaut, 1995). This also suggests the success of interventions upon such stereotype-driven category coactivations (Freeman & Ambady, 2011) will depend on our knowledge of whether they are acquired through learning or occur on the fly.

Temporal Dynamics in Top-Down Perception

One sometimes-overlooked facet of top-down perceptual effects in social psychology is their temporal dynamics. As the authors note, "Perception involves multiple component processes that come online and interact in a recurrent fashion within milliseconds of being presented with a stimulus" (Xiao et al., this issue, p. 258). Because processing throughout perceptual hierarchical pathways occurs over time, at any given moment, different points in the system may be more or less biased by top-down factors. It is indeed possible that fleeting biases, temporally preceding the experiential outcome of perception, may influence downstream cognition and behavior, if neural processes interact recurrently as a dynamic system (McClelland et al., 2010). This is a critical consideration, given top-down effects may not necessarily bias final all-"conscious" perceptions and responses but nevertheless have a fleeting impact on process.

As one example, predictive coding accounts argue that expectations can increase the readiness of context-congruent object recognition through impacts on preconscious perceptual processing, rather than biasing visual experience persistently (Bar, 2004; Gilbert & Li, 2013). One can imagine our perceptual world would be littered with inaccurate hallucinations if top-down expectations forced stable biased states in perception. Take the example of viewing a blow-dryer in a toolshed, which from a distance may appear similar to a drill (Bar, 2004). Although one possibility is that contextual expectation of objects found in a toolshed biases stable perceptual experience of the blow-dryer toward a drill in a persistent fashion, it is also plausible that such a perceptual modulation would occur only for a few hundred milliseconds before higher weighted bottom-up information floods the visual system to provide a more empirical perception.

Such a consideration is vital to debate of top-down effects upon cognition (Firestone & Scholl, 2015), which often overlooks the extent to which perception is a dynamic hierarchical process and its susceptibility to top-down influences does not require shifted conscious experience. For example, consider one debated case of top-down social perception, the case of speeded recognition of moral words (Gantman & Van Bavel, 2014). Whereas higher level cognitive biases could underlie the effect (Firestone & Scholl, 2015), it is also possible that social factors (either online or learned; see earlier in this commentary) tune relevant receptive fields early to more efficiently process these words perceptually. As we discuss earlier, investigation of the level of process both cognitively and neurally can speak to these issues. One can imagine in many cases of top-down effects in social perception, such as shifted outgroup race perception (Caruso et al., 2009; Freeman et al., 2011b; Krosch & Amodio, 2014; Krosch et al., 2013), persistent and stable perceptual bias may be less plausible than temporary impacts upon processing given the abundance of bottom-up information available.

This is all to say, with the additional dimension of time considered, it becomes increasingly plausible that top-down effects on perception occur at least at some point during processing given our knowledge of neural systems. Drawing any line between levels of processing, such as "perception" and "recognition," becomes an even murkier endeavor in the face of modern theory in neuroscience. It is indeed possible that perception itself is integral in recognition in manners and extents. In a recent study, Carlson, Ritchie, Kriegeskorte, Durvasula, and Ma (2014) had participants categorize targets as animate or inanimate. They found the distance of target neural patterns from an animate–inanimate decision boundary in multivoxel pattern representational space in inferior temporal cortex predicted their animacy categorization time. These findings suggest that the states of perceptual representations may themselves constitute canonically "higher order" recognition and response states. In line with modern dynamic connectionist models (McClelland et al., 2010), it is indeed possible that shifts in the state of any level of processing may entail, share, or provoke shifts at any other level. Of importance, it may be difficult to identify any such top-down modulations unless they are assessed continuously along the process, preceding final behavioral responses.

One model that has recently highlighted the dynamic nature of these perceptual effects is the dynamic interactive (DI) model of social categorization (Freeman & Ambady, 2011; Freeman & Johnson, 2016). The DI model is a recurrent connectionist model whereby multiple levels (e.g., perceptual cues, categories, stereotypes, goals) of the social perceptual process interact continuously, weighing in on category representation until the system achieves a steady state. Bottom-up perceptual cues activate categories, and these activations each activate associated stereotypes, which along with other top-down factors, such as goals, can feed back down and influence the degree of category activation. Importantly, multiple incongruent states (e.g., male and female perceptual categories) can be active in parallel during the process while the system dynamically allows them to compete until one comes to dominate as the steady state of the system. This perspective of dynamic competition over time between parallel incompatible states of a system has been observed in many branches of cognition, including motor decisions (Cisek, 2007), perceptual choice (Usher & McClelland, 2001), spoken-language comprehension (Spivey, Grosjean, & Knoblich, 2005), semantic categorization (Dale, Kehoe, & Spivey, 2007), social categorization (Freeman & Ambady, 2011), and interracial attitudes (Wojnowicz, Ferguson, Dale, & Spivey, 2009), to name several notable cases. This indeed bears important implications for top-down effects in social perception generally, as typically these systems settle into one stable state without any sign of the temporary multiple activations at the surface. In a recurrent connectionist and dynamic system, these temporarily active alternative states can influence processing downstream, potentially bearing consequence on later behavior.

In one case, consider gender categorization of a Black female. Female and Afrocentric cues upon the face activate strongly "female" and weakly "male" categories (Black faces are perceived more masculine than White faces; Goff, Thomas, & Jackson, 2008). Simultaneously, activation of the "Black" category may elicit related stereotype activations, such as "hostility," which in turn cascade back down and weigh in on category representation, partially activating "male" (Johnson, Freeman, & Pauker, 2012). Eventually, the abundance of bottom-up perceptual information allows for an accurate, confident "female" categorization of the face. However, at a certain time in the system, top-down factors impacted perceptual processing. Therefore, regardless of no evidence of any shift in visual "experience" of the face based on a perceptual outcome, the perceptual process was biased temporarily (see Freeman & Ambady, 2011; Freeman & Johnson, 2016). Such temporary biases could potentially influence downstream behavior, such as lesser preference for targets with incongruent gender-race stereotypes (such as Black females, or Asian males, who each activate both gender categories due to gendered stereotypes of their races; Galinsky, Hall, & Cuddy, 2013). In a recent study, we found stereotypes to bias voxel-pattern representations of social categories in the rFG, implying top-down effects upon the perceptual representation of a face (Stolier & Freeman, 2016b). However, these findings were observed in multivoxel patterns obtained from functional magnetic resonance imaging (fMRI), where the temporal resolution spans at least a couple seconds. Therefore, it is entirely possible that biases in these measurements occur only earlier in the process, and later these patterns reach less stereotypically biased states. From the perspective of the DI model and attractor neural network models in general, as the system settles into an attractor state (e.g., female), that is, completes a distributed representational pattern, it will meander toward other attractor states (e.g., male), that is, partially complete other representational patterns, if bottom-up cues or top-down social cognitive factors push the trajectory of the system toward those attractors (e.g., Black → hostility → male; Freeman & Ambady, 2011). Presumably multivoxel fMRI pattern analysis is sensitive to such patterns, but it is unclear at what moments during the perceptual process they would reflect due to the temporal resolution of fMRI.

A Temporally Dynamic Approach to Top-Down Effects

Dynamic and iterative models of social perception highlight the importance of evaluating the state of cognitive systems across time, as top-down biases may occur dynamically, and their influence may take on many forms at many different levels of processing. The need to more specifically delineate the functional nature, level, and temporal dynamics of top-down effects in social perception calls for methods sensitive to these distinctions. Specific methods are well suited for this endeavor.

Behaviorally, motion-tracking paradigms have recently become commonplace for assessment of dynamic shifts in functionally distinct cognitive processes (Freeman & Ambady, 2011). Due to the continuous updating of motor plans as cognitive states evolve in other brain regions, such as during social category perception (Freeman, Ambady, Midgley, & Holcomb, 2011a), motion-trajectories are influenced moment to moment by the current cognitive state. Therefore, by recording motion-trajectories, researchers can gain insight into perceptual and cognitive processes as they develop online over time. Typically, computer mouse-trajectories are measured during a task. Different components of the trajectory index specific cognitive processes that occur during the process, in addition to final response (for reviews, see Freeman & Ambady, 2010; Freeman, Dale, & Farmer, 2011). For instance, the amount of deviation of a motion trajectory toward an unchosen response, regardless of a clear-cut final response, can index degree of temporary parallel coactivation and competition between both states (e.g., temporary activation of male and female categories simultaneously in early processing). Indeed, regardless of clear-cut social categories perceived, temporary motor indices of competition between multiple perceptual categories (e.g., Black female activating the male category) predicted neural pattern similarity of categories in perceptual regions (Stolier & Freeman, 2016b). Moreover, the hand's direction of movement en route to either response can index with millisecond-resolution the relative accumulation of evidence in favor of each competing state across the time course of the process. Additional components of motion trajectories can even provide a window into specific cognitive processes occurring, such as when in time a stable state is achieved, dynamic competition, and abrupt transitions between multiple representations or processes (Freeman, Pauker, & Sanchez, 2016; Hehman, Stolier, & Freeman, 2016a).

In addition to dynamically sensitive behavioral methods, temporally sensitive neuroimaging methods can also provide insight into top-down influences in social perception. Both electroencephalography and magnetoencephalography (MEG) provide excellent temporal resolution, and adequate spatial resolution through source localization to infer the interplay of certain cognitive processes. Furthermore, they can be combined with one another and other neuroimaging technology. In one combined fMRI and MEG study, Bar et al. (2006) were able to observe connectivity of the OFC and FG, and that the presence of object expectations in the OFC preceded the FG by 50 ms. These methods may therefore identify the interaction of higher order and perceptual regions, and more specifically delineate the nature of their interactions, for instance, specifying whether perceptual regions were modulated by higher order top-down processes.

Conclusion

In their novel perceptual model of intergroup relations, Xiao et al. (this issue) outline the process through which top-down intergroup processes impact perception directly, which in turn uniquely mediates certain intergroup effects on behavior. This is, we hope, the first of many more specified models of how top-down perceptual effects impact social cognition and behavior. Furthermore, the authors emphasize the wide scope of top-down effects, bringing to the forefront many other sensory modalities through which social factors may impact perception and subsequent behavior. From this point on, as the authors note, it will be important to assess the relationship between top-down social perceptual effects and intergroup behavior. This key point applies across areas of top-down social perceptual models, including those in social categorization (Freeman

& Ambady, 2011), trait inference (Dotsch, Wigboldus, Langner, & van Knippenberg, 2008), and moral perception (Gantman & Van Bavel, 2014). Crucially, experimental manipulations may come to play a key role in determining the causal role of top-down perceptual modulations in predicting social behavior.

As social psychology and neuroscience come to integrate considerations from computational models of social cognition (Cunningham & Zelazo, 2007; Freeman & Ambady, 2011), such as recurrent connectionist and dynamical systems (McClelland et al., 2010), we believe it will be important to delve further into the intricacies of these models. Top-down influences in perceptual systems vary considerably in their functional nature (e.g., attention vs. expectation; online vs. learned), level of processing (e.g., early perceptual vs. high-level conceptual), and temporal profile (e.g., whether its impact is stable or only momentary during processing). Combining computational models, time-sensitive behavioral methodologies, and neuroimaging methods focusing on distributed representational patterns and the temporal interplay of brain regions may be powerful in helping to specify the functional nature and level of processing at which top-down effects occur. It is likely that such aspects will be important in understanding how interventions are best suited in cases of deleterious top-down effects of negative stereotypes or attitudes. Moreover, attending to the temporal profiles of these effects will help us to not miss many cases where top-down influences occur only temporarily in processing. Integrating such directions with Xiao et al.'s (this issue) model hold great promise for advancing our understanding of the dynamic interplay between perception and intergroup cognition.

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