Challenges and opportunities for top-down modulation research in cognitive psychology

Ramsey, Richard; Ward, Rob

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Title: Challenges and opportunities for top-down modulation research in cognitive psychology

Richard Ramsey[1] and Rob Ward[2]

[1] Department of Psychology, Macquarie University, Sydney, NSW 2109, Australia.

[2] Wales Institute for Cognitive Neuroscience, School of Psychology, Bangor University, Bangor, Gwynedd, Wales, LL57 2AS, United Kingdom

Correspondence: richard.ramsey@mq.edu.au

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Abstract

Studying social modulation of cognitive processes holds much promise for illuminating how, where, when and why social factors influence how we perceive and act in the world, as well as providing insight into the underlying cognitive mechanisms. This is no small objective; it reflects an ambitious programme of research. At present, based on the modal theoretical and methodological approach, we suggest that several challenges exist to achieving such lofty aims. These challenges span an overreliance on a simplistic dichotomy between "top-down" and "bottom-up" modulation, a lack of specificity about mechanisms that renders clear interpretations difficult, and theories that largely test against null hypotheses. We suggest that these challenges present several opportunities for new research and we encourage the field to abandon simplistic dichotomies and connect much more with existing research programmes such as semantics, memory and attention, which have all built diverse research platforms over many decades and that can help shape how social modulation is conceptualised and studied from a cognitive and brain perspective. We also outline ways that stronger theoretical positions can be taken, which avoid comparing to null hypotheses, and endorse methodological reform through fully embracing proposals from the open science movement and "credibility revolution". We feel that by taking these opportunities, the field will have a better chance of reaching its potential to build a cumulative science of social modulation that can inform understanding of basic cognitive and brain systems, as well as real-life social interactions and the varied abilities observed across the Autism Spectrum.

1. Introduction

The idea that what you know influences what you see is not a new one. Indeed, perceptual input is rarely completely encapsulated from other pieces of knowledge or information. While perception is driven "bottom-up" by stimulus features such as object shape, size, and position, perceptions are also influenced from "top-down" by our knowledge of the world. A well-known example is the word superiority effect (McClelland & Rumelhart, 1981), showing that knowledge of words affects perceptions of letters. Our understanding of human perception cannot be complete, therefore, without appreciating how the broader mental context -- including thoughts, beliefs, desires, and expectations, amongst many other factors -- shapes cognitive processes.

Turning to the present focus, top-down and bottom-up influences have also been investigated in social domains – situations that involve interactions between people (for reviews, see Bach & Schenke, 2017; Otten, Seth, & Pinto, 2017; Zeki, 2013). Social information has been shown to modulate how we perceive and judge other people, as well as how we act towards them (Otten et al., 2013). In addition, researchers have started to study the factors that modulate the links between perception and action; situations where visual and motor processes are processed in parallel or integrated somehow, such as during imitation and action observation. Indeed, research has investigated how social factors such as motives, group membership, context, prior experience and beliefs can have a top-down influence on the links between perception and action (for reviews, see Arnold & Winkielman, 2019; Bach & Schenke, 2017; Campbell & Cunnington, 2017; Chartrand & Lakin, 2013; Heyes, 2011; van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009; Wang & Hamilton, 2012). For example, imitative tendencies have been shown to be influenced by group membership (Gleibs, Wilson, Reddy, & Catmur, 2016; Rauchbauer, Majdandžić, Stieger, & Lamm, 2016), beliefs about animacy (Liepelt & Brass, 2010; Klapper, Ramsey, Wigboldus, & Cross, 2014), as well as pro-social primes and gestures (Cook & Bird, 2011; Cracco, Genschow, Radkova, & Brass, 2018; Leighton, Bird, Orsini, & Heyes, 2010; Wang & Hamilton, 2013). To date, therefore, a diverse set of top-down factors have been associated with social modulation and they have been studied across a number of perception and action processes.

As the examples above demonstrate, social modulation has come to encompass a wide range of influences. Indeed, as we unpack in the next sections, the term has a rather diffuse meaning at present, which is likely to hamper progress. Nonetheless, even with a loosely-defined term, contributions have been made to understanding perception-action links via the investigation of top-down modulation. One piece of added value, for example, is support for the idea that social cognition, as well as cognition more generally, cannot be understood by only studying component processes in isolation (Churchland, 2013). The complexity of social life and related cognition is reliant upon the interaction of many different mental processes (Adolphs, 2010; Frith & Frith, 2012), which requires the study of how signals are integrated within and between processors (Park & Friston, 2013; Bullmore & Sporns, 2009). Therefore, aiming to understand the relationship between social factors and links between perception and action has an intuitive appeal that goes beyond the narrow study of the specifics in question, and generalises to understanding basic processes of human cognition and brain function.

On this analysis, it seems logical and reasonable that social top-down modulation research has garnered broad appeal from researchers in many different aspects of psychology and neuroscience (e.g., Bach & Schenke, 2017; Otten, Seth, & Pinto, 2017; Wang & Hamilton, 2012; Zaki, 2013), as well as those in clinical and health disciplines who study atypical social information processing, such as Autism Spectrum Conditions (e.g., Cook, Barbalat & Blakemore, 2012). Although we feel the current approach has potential to be relevant and important across multiple disciplines, the research programme is in the early stages of development and like any new direction of research it is having teething problems. Indeed, we would argue that it is still finding its feet in terms of understanding its aims and tying those to relevant and rigorous theoretical positions and methodological approaches.

In light of this present context, therefore, in the current paper we aim to present challenges and opportunities for social top-down modulation research that study perception-action links (see Table 1). Although our present focus is on understanding links between perception and action, the set of challenges and opportunities we present are applicable to top-down modulation research in psychology more generally. As such, the general arguments that we present apply equally to studies of social perception and behaviour. We suggest that the most common approaches suffer from several theoretical and methodological limitations, which make it unclear what claims, exactly, are being supported by the evidence provided. These range from ambiguity over what social top-down modulation is and is not, a lack of specificity in the claims being made and a predominance of theoretical positions based on null-hypothesis testing. We outline how and why these present non-trivial challenges to firmer progress. We then put forward several opportunities for future research that we feel will help to overcome these limitations and push the research programme further in the future.

Table 1. Challenges and opportunities for social modulation research in cognitive psychology.

	Challenge 1	Challenge 2	Challenge 3
Description	Social top-down modulation needs a clearer definition	Specificity over mechanisms needs establishing	Theoretical and methodological reform is required
Example/s	- A neat dichotomy between "top-down" and "bottom-up" is unrealistic and hinders progress - "Social modulation" captures so many factors that we question its utility	- Mechanism vs. stimulus/context specificity is unclear - Research aims are unclear (e.g., basic systems vs. real-life relevance), which makes interpretation of effects difficult	- Testing against the null hypothesis of no modulation dominates and the "crud" factor is a concern - Levels of reproducibility and power are low or not yet demonstrated
	Opportunity 1	**Opportunity 2**	**Opportunity 3**
Description	Replace and avoid unrealistically neat divisions and umbrella terms	Benefit more from established research programmes	Improve theoretical reasoning and embrace methodological reform
Example/s	- Describe social factors in concrete and specific terms - Place firmer constraints on generality	- Domain-general knowledge from established literatures (e.g., semantic, memory, attention, and biased competition) are directly relevant and can inform the research programme	- Test alternative theories and predictions beyond the null - Use theory mapping tools - Embrace the "credibility revolution"

Note: The "crud" factor refers to the notion that to some degree everything is related to everything in psychology. As such, small, non-zero effects are difficult to interpret on their own because they could reflect complex, multivariate and non-theorised relationships (Meehl, 1990; Orben & Lakens, 2019). See section 2.3 of the main text for further details.

2. Challenges

2.1 *Social top-down modulation needs a clearer definition.*

We find the "social" and the "top-down" part of this terminology a hindrance to the development of the research programme. In the "social" domain, “top-down” currently appears to encompass a broad swathe of factors that could modulate behaviour in many different ways and be supported by many different cognitive and neurobiological mechanisms. Rather than representing a minor quibble over the specifics of a definition, we see the current dichotomic foundational structure as a major challenge to progress for several reasons.

First, at a basic level, it is not entirely clear what counts as top-down. Is it all non-stimulus-driven effects? If so, what constitutes "stimulus-driven" needs defining, and clear boundaries between the two types of modulation need setting. However, our view is that a neat division between top-down and bottom-up is likely to be overly simplistic and unrealistic. Real-life encounters frequently comprise a combination of factors, and while some would typically be “top-down” and others “bottom-up”, often it might be impossible to tell. You are waiting for a train and you see a work colleague. What happens next percolates from a complex brew of tonic top-down goals (e.g., get along with colleagues; advance within the workplace; self-promote; avoid conflict) and bottom-up stimulus activation (e.g., who exactly is this colleague?; what interactions have you had with them recently?; what emotional states, if any, does this colleague trigger?). If you were then polite but non-committal to this colleague, would that be a top-down or bottom-up effect?

To answer this question, one could imagine holding the task context constant (waiting for the train), and varying the stimulus factor (the colleague). But this cannot be a complete solution, as in real-world cases, stimulus-driven activity and rich associations between stimuli can lead to implicit task goals; that is, a "top-down" task set could be activated through "bottom-up" stimulus processing. For example, the associations activated from one colleague might in turn activate an implicit goal to approach; sight of a different colleague might lead to the activation of an avoidance goal. Therefore, a framework for studying integration and combination of factors is required. This is not to suggest that manipulating one factor and holding others constant is not an eminently sensible approach to scientific experimentation. Rather, it is to suggest that only attempting to understand processes by studying them in isolation is fundamentally limited. Instead, processes must be studied in isolation and in combination to more completely understand how they operate, as well as approximate their function in real life. In other words, we should estimate the degree of cognition that results from interaction between systems, such as between processors in the ventral visual stream and the theory of mind network (e.g., Ramsey, 2018a), as well as the degree that results from largely localised processing within each of these systems (e.g., Kanwisher, 2010).

Second, the same term or variants of "social modulation" are used to cover so many different social factors, which span motives, beliefs, group features and social context (e.g., competitive vs. cooperative), that we question its practical value. Indeed, if we stopped using this umbrella term completely, would we lose anything at all? Under the assumption that social signals of all kinds could modulate behaviour, could researchers, for example, just use a more descriptive term to describe the specific social factor of interest, such as a level of perceived attractiveness, group features or the aspect of the environmental context that has been manipulated? In fact, rather than losing anything, we may actually gain some precision by doing so. That is because, until we know otherwise, it is reasonable to suppose that different social factors may exert influence on perception and action by different mechanisms. For example, the influence of attractiveness on approach and avoidance behaviours (Kramer et al., 2020) might arise through very different mechanisms than the influence of pro- and anti-social interactions on imitation (Wang & Hamilton, 2012; 2013).

For these reasons, like others in more general forms of psychology (Awh, Belopolsky, & Theeuwes, 2012), we suggest that researchers should consider using more specific frameworks to guide the study of social modulations and biases (see Opportunity 1 below).

2.2 *Specificity needs demonstrating.*

A higher degree of specificity is required when making claims regarding top-down control in relation to the evidence. One pervasive issue concerns stimulus versus mechanism specificity (Adolphs, 2009). Is modulation specific to a social stimulus or does it reflect a more general process? This question does not raise doubt over the social stimulus being social. A face, a group of friends, or a dislike for someone who enters the room, is usually unambiguously person-related and social. Instead, it raises the possibility that the underlying mechanism that biases behaviour is squarely, or at least predominantly, domain-general and operates across all contexts to some extent including social settings. If we found that a social stimulus influenced perception-action links, that does not imply that domain-specific social cognition had any effect (Ramsey & Ward, in press). An experiment which uses only social stimuli to show social modulation is susceptible to this argument. For example, visual stimuli of fingers being raised produce congruency effects on finger-raising responses (Brass, Bekkering, Wohlschlager, & Prinz, 2000), but this does not necessarily imply a social process of imitation has been demonstrated (Ramsey, 2018b; Ramsey & Ward, in press). It implies that at some level, the stimulus code given to irrelevant finger stimuli overlaps with the stimulus code given to the imperative number stimulus (e.g., Hommel, 2009).

As further examples, work from our own lab could be viewed differently if a stronger non-social position was taken (Klapper et al., 2014). Although the work by Klapper and colleagues (2014) demonstrates clearly that stimulus and belief cues to human animacy interact to influence behaviour in a social context, it remains unclear if such interactions are mediated through largely specialised and domain-specific mechanisms or something more general. In fact, without any specific evidence to the contrary, we now would seek to explain this effect as domain-general mechanisms of cognitive control operating over domain-specific social representations (Ramsey & Ward, in press). Likewise, priming a social construct, such as helping or harming others, can affect stimulus-response compatibility measures that are purportedly associated with imitative tendencies (Wang & Hamilton, 2013). The default interpretation of such findings focusses on the operation of systems dedicated to social information processing, rather than more general systems (Wang & Hamilton, 2013). Interest in highly "social" explanations, such as affiliative goal activation (Chartrand & Bargh, 1999), motivation to create moral communities (Boehm, 2000), and active-self models, in which pro-sociality is assimilated into the sense of self (Wang & Hamilton, 2013) are understandable. These kinds of explanations tap into important ideas of the moral structure and even the evolved basis of humanity.

However, given that powerful workhorses of cognition such as alerting, filtering, orienting and prioritisation are, by definition, domain-general and operating across social and non-social contexts (Corbetta, Patel, & Shulman, 2008; Petersen & Posner, 2012; Ptak, 2012; Duncan, 2010), we feel the first hurdle to address is to what extent social modulation effects can be understood in terms of domain-general mechanisms. For example, to what extent might different kinds of prosocial priming produce an attentional bias towards human stimuli? In other words, general processes of control that operate through ventral and dorsolateral frontoparietal cortex could play a much bigger role in modulating links between perception and action than has been given credit so far (Campbell & Cunnington, 2017; Ramsey & Ward, in press). That is, when thinking about findings from social modulation studies, before considering how wide and significant are the potential implications, first consider how well-studied mechanisms such as attentional bias and shared perception-action codes might explain the findings.

The combined result of this lack of specificity is that the purpose and type of research being undertaken is unclear. For instance, it is unclear if research is attempting to model systems and processes to address basic understanding, or estimate effects that have practical meaning in real-life, or a combination of both aims. Both aims seem possible, but researchers should be clear on the scope of the work. Being clear on these issues matters because it directly impacts the type of interpretations that can be made on the data and how one may evaluate whether the method is appropriate for the purpose. For instance, if one is trying to draw conclusions about cognitive processes, and we know only that a social factor has influenced perception and/or action in some way and through some unknown mechanism, then the lack of mechanism-specificity blurs the interpretation of the effects. As a consequence, a higher bar needs to be set for what type of evidence demonstrates a specific claim.

Top-down modulation research is not alone in having clear limits on specificity either; concerns regarding the specificity of claims being made have recently been levelled at a much more established research programme that is concerned with recognising emotions from facial movements (Barrett, Adolphs, Marsella, Martinez, & Pollak, 2019). For example, contrary to the common view in science and society, facial configurations and expressions of emotion are not uniquely linked. That is, people do not always feel unhappy when they frown or happy when they smile. Consequently, the observation of a smile alone is not diagnostic of a particular emotional state. Instead, the evidence to date suggests that there is a much coarser mapping between facial movements and emotional states, which varies substantially across people and contexts. One implication of this work is that before firm conclusions can be made about specific relationships, a higher standard of evidence is required. Another implication is that a lack of specificity is a much more general problem for cognitive psychology and it may require more general solutions (see Opportunity 2 below).

2.3 *Theoretical and methodological reform is required*

Much like psychology research in general (Meehl, 1967; Rouder et al., 2016), alternative hypotheses appear to default to a null hypothesis – i.e., no top-down modulation. This seems like a straw man hypothesis, given what we know about "lower-level" processes, such as vision, which are not completely encapsulated from the influence of other systems. For instance, neuroscience research has shown that aspects of the visual system, which process elemental visual properties, such as colour, form and motion, are influenced by systems that extend beyond the visual system (Gilbert & Li, 2013). If basic components of vision are not completely encapsulated from the operation of other systems, it seems highly unlikely that more complex processing units would be. Although the nature of information encapsulation continues to drive lively debate from a cognitive standpoint (see Firestone & Scholl, 2016 plus the associated peer commentary), we find a strong version of Fodor's module definition untenable because it relies, in part, on complete information encapsulation, amongst other things[1] (Fodor, 1983). Instead, we favour a weaker form of modularity that does not require complete information encapsulation (Carruthers, 2006; Ogilvie & Carruthers, 2016). Under such a view, information processing systems are relatively specialised for particular processes, such as vision, whilst also being modifiable by other systems (Ogilvie & Carruthers, 2016). What remains, therefore, are questions regarding the extent to which processes (social or otherwise, top-down or otherwise) modulate perception-action links, in what situations and by how much?

Such questions make considerations of the "crud" factor particularly relevant. The notion of the "crud" factor was developed in personality research and suggests that to some (possibly small) degree everything is related to everything, and therefore we should be especially cautious when interpreting small non-zero relationships (Meehl, 1990; Orben & Lakens, 2019). Considered in the context of the present focus, given the possibly infinite set

[1] Fodor's (1983) definition of a module included fulfilling a range of properties, such as: domain-specificity; information encapsulation; obligatory firing; fast processing; shallow outputs; limited accessibility; innate; fixed neural architecture.

of inter-relationships between social variables and cognitive processes, there is a huge space for small but non-zero relationships to emerge, which prevent a single straightforward interpretation. Indeed, the results could emerge from a multivariate set of complex and interrelated causal pathways, which were not considered by researchers (Orben & Lakens, 2019). Here, therefore, crud factor effects are distinguished from effects that reflect sampling error or noise, which would not be replicable. Instead, crud factor effects are real in the sense that they are replicable, they are just not interpretable because they reflect complex, multivariate and non-theorised relationships (Meehl, 1990; Orben & Lakens, 2019). On this view, we should not be surprised that manipulating social variables could influence links between perception and action in some way; in fact, we should expect it. As a consequence, therefore, it seems important to go beyond a comparison to the null hypothesis and be explicit and clear regarding what alternatives are being considered (Rouder et al., 2016). Failure to do so will produce a situation that mirrors many other fields of research: given sufficient power and sensitivity, there is likely to be a non-zero relationship, but why does it matter? How big is it? Are there credible alternative theoretical positions? If not, the value of the work remains ambiguous.

A further limiting factor on the potential value of the work relates to methodological reform. Before debates run on for decades regarding social top-down modulation, the methodological and empirical bar should be adjusted and raised before strong claims can be made about specificity or any other aspect of social modulation. As pointed out in many domains of psychology, reproducibility levels are low (Open Science Collaboration, 2015), which presents a substantial roadblock to the development of a cumulative science, and we see no reason why top-down modulation research would be any different. In fact, a recent meta-analysis has shown that the influence of social factors on one purported measure of imitation is null or negligible (Cracco, Bardi et al., 2018). In addition, other studies using much larger sample sizes than the original studies have failed to replicate effects of pro-social primes on imitation (Newey, Koldewyn, & Ramsey, 2019), as well as effects of emotional expressions and aspects of personality such as narcissism on imitation (Butler, Ward, & Ramsey, 2015; Darda, Butler, & Ramsey, 2019). Moreover, top-down effects are likely to be small to moderate in size, much like effects generally in psychology, which presents a substantial challenge to performing powerful research, but also an opportunity to change study designs and how one may interpret small effect sizes (see Opportunity 3).

As a counter-point, however, it should be noted that a small but increasing number of studies have used more robust methods (e.g., larger sample sizes, multiple experiments, pre-registration) and show evidence for social modulation (e.g., Cracco et al., 2018; Genschow et al., 2020). Such studies are an encouraging sign for the field, although they stop short of providing evidence that the effects rely on a social or specialised mechanism. As such, it is worth stressing that estimating the presence of non-zero effects in a robust manner does not license an inference about the underlying system controlling such effects. In summary, the need to address methodological reform is clear from these examples and features as one of the main drivers of this special issue.

3. Opportunities

3.1 *Move on from "social", "top-down", and "bottom-up" terminology and place firmer constraints on generality.*

Researchers may consider avoiding and replacing terms like "top-down" and "bottom-up" (Awh et al., 2012), as they are unnecessary and uninformative under alternative frameworks (see below). Indeed, a host of cues continually fight to dominate attention with many different and varied features providing bias. And we also have a long history of prior experience to add to this picture, which shapes basic perceptual processes. The upshot is that a simple top-down versus bottom-up dichotomy may not be that useful because it is based on an over-simplification, one that mirrors suggestions in other domains of cognitive science regarding the division between automatic and controlled processes (Melnikof & Bargh, 2018). Instead, nearly every situation is a combination of bias from a range of different sources. How they mesh and compete is interesting, but we do not see how vague terms such as top-down and bottom-up remain useful.

It seems simpler to state the specific form of bias – facial attractiveness, level of hunger, motivation to get fitter, addiction to smoking, rather than catch-all terms like top-down and bottom-up. Without clear and specific operational definitions, the terms quickly lose their meaning, especially when there are many different flavours of what people mean by the terms (Lenartowicz, Kalar, Congdon, & Poldrack, 2010; Poldrack et al., 2011). A move towards more descriptive and concrete terminology for social factors also addresses our concerns about the utility of studying "social modulation" in an abstract sense, when different social factors may potentially influence cognition in different ways. Such a view also reinforces recent suggestions that greater progress would be made in psychology if more descriptive research was performed in general (Yarkoni, 2019), and if there was a greater willingness to consider functional research, which documents how environmental features influence behaviour, together with research that aims to understand cognitive mechanisms (Hughes, De Houwer & Perugini, 2016).

To be clear, we are not arguing that no progress at all can be or has been made using such terms. Existing frameworks do exist where these terms and associated concepts are of central importance (Bach & Schenke, 2017; Bar et al., 2006; Bar, 2009; Friston, 2010; Otten, Seth, & Pinto, 2017; Zeki, 2013). On the one hand, therefore, we feel that if one wants to use these terms then it seems sensible to embed them within these existing frameworks. On the other hand, however, we offer caution in doing so. As our line of argumentation has put forward, these frameworks may serve to demonstrate that many domains of psychology and brain science may suffer from using fuzzy and overly simplified distinctions between bottom-up and top-down processes. Indeed, we feel the distinction between top-down and bottom-up, much like divisions between automatic versus controlled processes (Melnikof & Bargh, 2018), can be easily used in non-informative ways. Therefore, the use of such terms may be a limiting factor in those frameworks also.

The predominance of the distinction may hinder progress in other ways also by unnecessarily shackling the development of alternative frameworks. Other lines of research could prosper, for example, by taking a different starting point, which favours a multi-dimensional approach rather than a strong reliance on specifying a neat division between top-down and bottom-up processes. Research in psychopathology, for example, has shown that there are benefits from considering questions through a dimensional rather than categorical lens (e.g., Conway et al., 2019). Under a more dimensional approach, therefore, one could expect psychological processes, including social modulation, to reflect a continual blend of multiple sources of bias that interact with each other (Zaki, 2013). Finally, it might also be worth acknowledging that simple distinctions may have more use in some domains than others. For example, it seems eminently sensible to use an established framework, such as object perception (Bar et al., 2006; Bar, 2009), as a template to help guide the study of social perception. Whilst there appear to be clear benefits of doing so, the scope of such an approach is also likely to be limited. Indeed, such a framework may become less useful when explaining more complex phenomena, such as modulatory influences in social interactions. Everyday examples of social interactions serve to demonstrate that neat divisions may need to be replaced by a default expectation for complex relationships that involve integration between multiple systems (Zaki, 2013).

A companion piece to rethinking terminology is to place explicit constraints on the generality of reported findings (Simons, Shoda, & Lindsay, 2017). To do so, it is important to be explicit about the proposed limits, scope and range that the reported effects may have. Setting proposed boundary conditions on your findings makes it easier for others to attempt to generalise the findings or challenge and falsify them. For example, do you anticipate the reported effect to be restricted to a specific social context with a particular individual? Or is it a more general process that applies to the self in any future situation? Would you expect it to have obvious social consequences in real life or is the approach more of a demonstration that targets basic systems? Would you expect the effect to vary considerably across individuals or contexts? The process of placing clear and obvious constraints on generality helps to avoid researchers inadvertently mis-specifying a proposal and spending time needlessly using resources to test it. Placing explicit constraints on generality would be a valuable addition to clarify the scope and range of expectations regarding social top-down modulation.

3.2 *Make better use of developments in more established research programmes.*

More established research programmes and frameworks should be harvested much more for insight and guidance. We should not reinvent the wheel in a social guise. Well-studied and established frameworks can be particularly informative. For example, non-social top-down control research in psychology (Theeuwes, 2004; 2010; Awh et al., 2012), neuroscience (Bar, 2003; Bar et al., 2006; Beck & Kastner, 2009), and neuropsychology (Humphreys, Riddoch, & Price, 1997) would seem sensible places to start. Elsewhere we have argued that research in social cognition would benefit from taking as strong a "non-social" stance as possible (Ramsey & Ward, in press).

Frameworks that go beyond top-down control can also be informative because social cognition is likely to rely, in part, on many of the same general processes that operate across all domains. For example, proposals from semantics, memory, motor control, and attention would be valuable in helping to guide expectations and the design of the research programme. This is especially true if one minimises the expectation for the role of specialised processes and instead emphasises more general-purpose mechanisms in social neuroscience (Spunt & Adolphs, 2017; Ramsey & Ward, in press).

The semantic cognition literature, for example, supports a division between representation and control systems in understanding meaning (Jefferies, 2013; Lambon Ralph, Jefferies, Patterson, & Rogers, 2017). The representation system is associated with the acquisition and long-term storage of conceptual knowledge and relies on distributed sensory, motor and affective systems, plus a supramodal hub in the anterior temporal lobes. The control system utilises this semantic information in line with task- and context-specific requirements, thus making sure that relevant aspects of knowledge are retrieved and used at the appropriate time and place. The control system spans ventral and dorsolateral frontoparietal cortex, thus covering cortical territory predominantly associated with cognitive control and executive functions (Duncan, 2010; Peterson & Posner, 2012). A strength of this semantic cognition framework, as well as the key division between representation and control systems, is that they are based on a host of complementary approaches and levels of description, which span neuropsychology, computational modelling, neurostimulation, neuroimaging and comparative work (Chen et al., 2017; Jefferies, 2013; Lambon Ralph et al., 2017).

Translating this semantic framework into the social domain would entail specialised sensory processors for person features (representation), but general processors for controlling such social representations (Binney & Ramsey, 2020). Under this view, bias in the system (e.g., social modulation) can arise from representational and/or control systems and it is important to be clear which one you are measuring and researchers rarely, if ever, do this in cognitive psychology or neuroscience studies (including perception and action coupling). As reviewed recently (Campbell & Cunnington, 2017), this is particularly relevant for some perception and action links, which rely heavily on inferior frontal and parietal cortices, because these brain regions are implicated in both social processes (e.g., Rizzolatti & Sinigaglia, 2010) and domain-general attentional processes (e.g., Duncan, 2010). As such, on a brain network level of description, functional and anatomical specificity would need demonstrating.

A further general framework to consider how to conceptualise social modulation is biased competition (Desimone & Duncan, 1995; Duncan, Humphreys, & Ward, 1997; Beck & Kastner, 2009). Biased competition models offer a way to conceptualise how signals from different processing components may be integrated. Such frameworks characterise the brain as a complex information processor that has many specialised processors operating in parallel. For example, in the visual domain, there are dedicated processors for form, motion, colour, as well as complex feature combinations. Examples outside of the visual domain include processors largely dedicated to memory, planning, and a range of executive functions. Parallel processing systems of this sort present a computational problem, however, which concerns how signals are integrated across processors. Indeed, for coherent behaviour, the activity of different information processors and associated neural networks must be coordinated so that a single object or event guides response effectors at any one point in time. Behaviour would become disorganised and ineffective, for example, if goals, such as meeting a friend at the train station, could not integrate with other signals such as remembering which platform and at what time your friend is due to arrive. Likewise, behaviour would also breakdown if sensory signals, such as the sounds and visual inputs of trains arriving and departing, overwhelmed and interfered with other cognitive processes, such as your current goal to meet your friend.

Biased competition frameworks solve the problem of signal integration by allowing bias for an object or event in one processor to propagate through the network until it resolves on a “winning” object or event. Such competition is meant to operate in ubiquitous fashion across the entire brain, and therefore would integrate neural activity within and between the neural networks associated with person representation and control processes. Within a biased competition framework, therefore, social modulation can be treated like any other form of bias, whether it takes a social or non-social form. Indeed, a given type of bias is not special in any sense, but instead just reflects another form of bias in the system. This offers the opportunity to integrate multiple signals – both social and non-social – without the need to worry about hard-to-define terms and possibly unrealistically strict divisions between concepts like “top-down” and “bottom-up”.

Turning to another established literature, we consider how learning and memory systems can add to understanding social modulation. Given that memories and prior social experiences shape perceptions, it seems equally valuable to harness insight from memory research (Amodio, 2019). Amodio (2019) makes clear that social cognition research can benefit in numerous ways from considering the knowledge obtained about learning and memory systems across decades of research spanning multiple methods, as well as species, culminating in thousands of studies. For example, learning and memory research in cognitive neuroscience has identified several forms spanning episodic, semantic, instrumental and aversive conditioning, as well as habit. These forms of learning and memory rely on different neural networks and each one can link to multiple response channels (e.g., planning, impressions/judgments, affect, action and avoidance). Rather than largely ignoring this literature, it makes sense to exploit it in relation to social modulation research as it would appear to make clear, obvious and relevant predictions regarding different aspects of social cognition.

In terms of demonstrating specificity of the claims being made, extensive solutions have been put forward by authors in another social domain (emotion perception from faces) that are extensive and not only relate to specificity, but reliability and generalisability (Barrett et al., 2019). A detailed description of the specific solutions proposed is beyond the scope of this article, but it remains clear that such guidance exists and the importance of not engaging with such issues is clear. In short, if older and more established research programmes could benefit from such proposals, it seems reasonable that principles of specificity (in multiple forms), reliability and generalisability are worth considering in relation to newer research programmes such as top-down modulation in perception-action coupling.

Many other existing frameworks could also be of considerable value; here we just present a few illustrative examples of possible ways forward. The more general aim for the programme would be to avoid the danger of remaining encapsulated from these domains of human cognition and brain research, as they seem relevant on many levels and the differences may have been exaggerated in the past.

3.3 *Improve theoretical reasoning and embrace the credibility revolution.*

To alter the default position, researchers could seek alternatives to the null hypothesis. In the case of underlying systems, for example, researchers could probe the extent to which social modulation reflects bias between representational systems (e.g., different person representations biasing each other) or, alternatively, if it reflects a form of failure in control systems. Control systems allow cognition to maintain a task-relevant focus. Priming from irrelevant stimuli can therefore reflect a failure, perhaps a very mild failure, of control systems to maintain task-relevant activity. As we hope is obvious, social modulation arising from an inability to exert complete task-relevant control would lead to a different type of interpretation regarding the functional value of the modulation when compared to modulation arising from bias in a person representation system such as face, body, affective or theory of mind representations.

To illustrate how research questions can be moved on in this way, consider Bach and Tipper (2007), who found that visuomotor compatibility effects (e.g., the relative ease of pressing a foot-switch when responding to an image of a footballer as compared to an office worker) could influence social attributions. In their case, a stimulus person would be perceived as more athletic if associated with the footballer-footswitch stimulus-response pair. A question arising is, does this effect demonstrate a functional capacity, by which statistical associations in the environment are used to a maximum degree, or does this reflect some leakage, or failure of control, in properly insulating task-specific processing from irrelevant information? Tipper and Bach (2008) later investigated this further to find that in fact the effect is likely based on a failure of control, a misattribution of the self's visuomotor fluency to the actor. Of course, bias could operate in both representational and control systems as well as between these two systems. Addressing such theoretical positions, no matter what the outcome, would inform the type of mechanism underlying bias and give an insight into the functionally relevance and value.

Another complementary approach to improving theoretical development would be to use tools that aid theory exposition. In order to clarify theoretical positions and aid cleaner and more efficient comparisons between perspectives, researchers could consider using the newly developed theory mapping tool (Gray, 2017; www.theorymaps.org). Theory mapping in this way enables researchers to express their theoretical position in a visual form using a common set of symbols. Given that the topic in question is complex, such an approach may be one way to help reduce mis-characterisation of other people's positions and the subsequent testing of mis-specified alternative theories.

If we change gear and consider the "credibility revolution" that is taking place in psychology (Vazire, 2018), much has been written about the issues associated with low reproducibility and the need to embrace methodological reform (Chambers, 2017; Simmons, Nelson, & Simonsohn, 2011; Open Science Collaboration, 2015; Munafò et al., 2017; Ramsey, 2020). To enhance the quality of the evidence provided, researchers interested in how perception-action links can be biased by social signals need to raise the bar for what counts as convincing evidence for what top-down modulation is and why it is relevant. There have been many sensible suggestions put forward for how and why to embrace open science using more rigorous methods, which we encourage social modulation researchers to embrace (Chambers, 2017; Munafò et al., 2017; Vazire, 2018; Zwaan, Etz, Lucas, & Donnellan, 2017).

Rather than repeat these very sensible prior suggestions, here we will focus on one specific issue that we see as particularly important for social modulation research, but which is likely to apply across the board in psychological science. Given that the anticipated effects are likely to be modest, a first basic aim would be to show that an effect is reliable, in the sense that it replicates with an acceptable degree of precision. Also, and of particular relevance to social top-down effects, it would make sense to consider the extent to which such effects have the potential to accumulate over time (Funder & Ozer, 2019). That is, the measurable effect (bias) produced by social signals (i.e., top-down modulation) in a one-off instance may be small, but if that is likely to be experienced 20 times a day, 5 days a week, then real-life effect and consequence may be different. For example, if you work alongside a colleague who you find attractive or you work in a cooperative/competitive context, the effects of each social episode may add up to something more than the one-off exchange. Not only that, such effects may only be measurable after longer exposure, which brings up questions about dose-response that also seem relevant. This of course would need to be demonstrated empirically with either longitudinal work or work that measures how effects modulate over time with repeat exposures to the same social modulation. It also reinforces the recent suggestion that basic research in brain science could benefit from engaging with research in real-world settings, so-called real-life neuroscience (Redcay & Schillbach, 2019; Shamay-Tsoory & Mendelsohn, 2019).

4. Conclusion

In conclusion, we argue that research aiming to understand how social factors modulate links between perception and action face several challenges that limit progress. To combat these challenges, we outline opportunities to reform the research programme. Opportunities include rethinking an overreliance on simplistic and unrealistic dichotomies (e.g., “top-down” vs. “bottom-up”), learning from more established research programmes, such as semantics, memory and attention, as well as embracing proposals for theoretical and methodological reform emanating from the “credibility revolution”. We feel that taking these opportunities seriously will provide a springboard for the emergence of a cumulative science of social modulation that can inform understanding of basic cognitive and brain systems, as well as real-life social interactions and the variety of abilities observed across the Autism Spectrum.

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