

## Review

## Majority influence in children and other animals

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## ABSTRACT

We here review existing evidence for majority influences in children under the age of ten years and comparable studies with animals ranging from fish to apes. Throughout the review, we structure the discussion surrounding majority influences by differentiating the behaviour of individuals in the presence of a majority and the underlying mechanisms and motivations. Most of the relevant research to date in both developmental psychology and comparative psychology has focused on the behavioural outcomes, where a multitude of mechanisms could be at play. We further propose that interpreting cross-species differences in behavioural patterns is difficult without considering the psychology of the individual. Some attempts at this have been made both in developmental psychology and comparative psychology. We propose that physiological measures should be used to subsidize behavioural studies in an attempt to understand the composition of mechanisms and motivations underlying majority influence. We synthesize the relevant evidence on human brain function in order to provide a framework for future investigation in this area. In addition to streamlining future research efforts, we aim to create a conceptual platform for productive exchanges across the related disciplines of developmental and comparative psychology.

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## 1. Introduction

The majority widely impacts our daily lives. The clothes we wear, the foods we eat, the phrases we use in a polite conversation; they are all regimented by the majority, often more than we know or like to admit. Sometimes, we even adjust our behaviour to the majority despite our personal preferences or even against better knowledge (Cialdini and Goldstein, 2004). The experimental demonstration of individuals knowingly giving false responses in order to conform to a majority of peers is amongst the most important and certainly most discussed findings in Psychology (Asch, 1956). In many of today's societies, majority influence in general, but especially yielding to a majority against one's own preferences has a bad reputation as essentially lying out of weakness of character. Despite this negative perception of the phenomenon, majority influence crucially structures human culture by promoting in-group homogeneity and between-group heterogeneity, ensuring temporally stable variation across groups, the very foundation of cultural evolution (Boyd and Richerson, 2009; Henrich and Boyd, 1998).

In contrast to our knowledge on majority influences in human adults (Bixenstine et al., 1976; Cialdini and Goldstein, 2004), we still know little about the extent to which children and other animals are influenced by the majority, and thus about the developmental trajectories of this intriguing social behaviour, both ontogenetically and phylogenetically. In this review we attempt to synthesize the disparate but related bodies of evidence in developmental psychology, comparative psychology and cognitive neuroscience to create a conceptual framework within which future studies in these areas might interrelate more effectively. Therefore we propose a set of new and old conceptual distinctions that allow a concise perspective on the existing evidence: (1) We use *majority influence* as a general term to summarise the more specific categories 2 and 3. (2) We use *majority-biased transmission* as a mechanism-neutral term, defined solely by the observable outcome, characterized by the increased likelihood of naïve observers to acquire the behaviour of the majority position relative to no social influence. (3) We use *conformity* as a second mechanism-neutral term, defined solely by the observable outcome, characterized by observers discarding their personal behavioural tendency in favour of the behaviour of the majority. Importantly, we propose to organize the majority influence definitions along this dichotomy of naïve vs. experienced (i.e. in possession of prior knowledge and/or preferences) individuals for the reason that social information may ground differently in individuals based on this specific state-quality. Whereas the behavioural end-result of acquiring the majority behaviour may be the same in both cases, and hence the ramifications on the level of cultural

diversification, the operational distinction between majority influences in naïve vs. experienced individuals may be the necessary impetus for investigating more closely the mechanisms and tradeoffs revolving around “conforming” to majorities (see van Leeuwen & Haun, in press).

To give a realistic scope to a review like this, we need to restrict our goals: since comprehensive reviews of conformity in both adults (Bond and Smith, 1996) and teenagers (Steinberg and Monahan, 2007) exist, we review existing evidence for majority influences in children under the age of ten years only. We furthermore review a selection of relevant studies with non-human animals. Given their relevance for arguments relating to the phylogenetic origin of human social behaviours (Haun et al., 2010; MacLean et al., 2012) we focus largely on non-human primates, admitting rare excursions to non-primate species if studies are of particular relevance. The integration of results from human and non-human studies on majority influence is still a risky endeavour and riddled with inconsistencies in both conceptual distinctions and methodologies. Thus, rather than hoping to provide a definitive integration, we hope to provide a common framework at a time when a joint effort is both possible and necessary.

## 2. Behavioural patterns under majority influence

### 2.1. Majority-biased transmission

*The increased likelihood of naïve observers to acquire the behaviour of the majority.*

Majority-biased transmission refers to the increased likelihood for naïve individuals to end up with the behaviour of the majority, where the likelihood of adopting the majority strategy is evaluated relative to the likelihood to adopt that same trait in the absence of inherent behavioural tendencies or social information (Haun et al., 2012). Importantly, this definition thus refers to a behavioural pattern only. No claims are being made regarding the underlying mechanism(s).

#### 2.1.1. Majority-biased transmission in children

Studies documenting majority-biased transmission in children are rare. Recent work by Flynn and colleagues investigated transmission of new tool-use techniques during natural interactions amongst preschool children (Flynn and Whiten, 2010; Whiten and Flynn, 2010). In these studies, one individual from a group of children is trained on each of the two available strategies to gain a reward from a puzzle box. After the trained individuals are reunited with their respective peer groups, researchers track the transmission of knowledge across the groups as well as the occurrence of alternative strategies. In general, children tended to end up with the technique that was used most frequently in their group (Whiten and Flynn, 2010).

Importantly for the purpose of this review on majority influences, however, is the consideration that in these studies, the participants were not exposed to a majority and minority of group members. Since only one strategy gets seeded into the group, it is hard to assess whether the children were adopting the strategy that most others were using or merely copying the only strategy that was demonstrated in the group. Two recent studies tested majority-biased transmission in children more directly. In one study, three-year-old children watched a group of adult demonstrators labelling a novel object. While the majority of demonstrators used label X, the minority used label Y. Children tended to adopt the label demonstrated by the majority (Corriveau et al., 2009). Moreover, children later preferably relied on information provided by a single member of the majority more than on information provided by the dissenter from the earlier demonstration (Corriveau et al., 2009). The activity of 'labelling', however, might be particularly prone to majority influence since language-use inherently relies on consensus: The level of consensus among speakers will determine the functionality of the label directly. Hence, we might expect children to be more likely to follow a majority when learning new labels than when learning how to use a tool. In another recent study, children were exposed to two different sets of demonstrations regarding the use of a food-dispenser, thus a consensus-independent skill. Observers saw peers from their own kindergarten group interact with a food dispenser in 2 different ways. A majority (3 demonstrators) used strategy X to retrieve food, while a minority (1 demonstrator) used strategy Y to retrieve food from the same dispenser. A third, equally obvious strategy Z was never demonstrated. Two-year old children copied the behaviour demonstrated by the majority more often than both the minority behaviour and the undemonstrated option. Children also copied the majority more often than might have been expected in absence of any behaviour-inherent or social information (Haun et al., 2012).

### 2.1.2. Majority-biased transmission in non-human animals

Open diffusion studies, similar to the ones described above, have also been conducted in several species of non-human primates (hereafter called 'primates'). Similar to children, primates showed a tendency to end up with the technique that was used most frequently in their group (e.g. chimpanzees: Bonnie et al., 2007; Hopper et al., 2011; Whiten et al., 2005; capuchins; Dindo et al., 2009). However, albeit important for our understanding of social learning capacities of primates, these studies are hard to interpret in terms of majority-biased transmission for the same reasons as outlined above (see also van Leeuwen and Haun, in press). More directly relevant results on primates' majority-biased transmission comes from the same study as addressed in the previous section (Haun et al., 2012). Again, both chimpanzee and orangutan observers saw conspecifics from their own social group interact with a food dispenser with a majority (3 demonstrators) using strategy X, a minority (1 demonstrator) using strategy Y and a third, equally obvious strategy Z that was never demonstrated. Similar to 2-year old human children, chimpanzees

copied the majority behaviour more often than both the minority behaviour and the undemonstrated option. They also copied the majority more often than might have been expected in absence of any inherent strategy preferences or social information. Interestingly, chimpanzees copied the third, undemonstrated strategy more often than the strategy demonstrated by the minority, which could indicate an active avoidance of ending up with the minority strategy. In contrast, orangutans showed no preference for the majority strategy over the other two alternatives (Haun et al., 2012).

Additionally, studies in rats and pigeons have shown that the likelihood of naïve individuals to copy the food preference of the majority increased linearly with the size of the majority (rats: Chou and Richerson, 1992), and that the solution to a food-related task was acquired linearly faster when demonstrated by an increasing number of tutors (pigeons: Lefebvre and Giraldeau, 1994). More recent studies have shown that also sticklebacks (Pike and Laland, 2010; Webster and Hart, 2006), dogs (Kundey et al., 2012) and even fruit-flies (Battesti et al., 2012) are more likely to acquire the majority behaviour than expected based on the likelihood to adopt that same strategy in absence of any inherent strategy preferences or social influences. In summary, it appears that both children and other animals display majority-biased transmission.

### 2.2. Conformity

*Tendency of minority observers to forgo their own behavioural tendency by adopting the behaviour of the majority.*

Conformity occurs when individuals forgo their knowledge and/or behavioural preference in order to adopt the majority strategy. This definition is extracted from social psychology experiments in which participants knowingly give false responses when faced with an erroneous majority. Formal models of social learning use the term conformity to describe a scenario in which the likelihood with which an individual might copy the majority strategy must be significantly larger than the relative size of the majority – see Section 3 (Boyd and Richerson, 2009; Efferson et al., 2008; Eriksson et al., 2007; Henrich and Boyd, 1998). This use of the same term to refer to two different phenomena in two different but related fields of investigation has caused a lot of confusion. We hope that in the course of this review, we can make the important distinctions obvious (see also Claidière and Whiten, 2012; van Leeuwen & Haun, in press). The literature on conformity in adults has been summarised in other reviews (Bond, 2005; Bond and Smith, 1996; Cialdini and Goldstein, 2004). Based on a large body of evidence we here aim to give an overview of the general dynamics of conformity in human adults, thereby creating a backdrop against which we can discuss the studies with children below: conformity occurs across a wide set of cultural contexts, but varies in its extent from culture to culture (Bond and Smith, 1996), coinciding with differing socialization values (Ellis et al., 1978). Generally speaking, adult females conform more than males (Bond and Smith, 1996; Eagly and Carli, 1981). The frequency and strength of conformity also varies within the same culture due to situational determinants (Bond and

Smith, 1996): Individuals conform more when the stimuli are more ambiguous – i.e. if the amount of noise relative to the signal in the stimulus is increased, resulting in a decrease of subjects' confidence in their own judgements (Asch, 1956). When offered incentives for accuracy adults conform less when tasks are easy, and more when tasks are hard (Baron et al., 1996). Furthermore, an effective majority needs to include at least three peers (Asch, 1956; Bond and Smith, 1996); further increases in majority size above three still increase the number of conform responses, but the effect is not proportional to the increase in majority size, but diminishes with increasing number of confederates (Latané, 1981; Latané and Wolf, 1981; Tanford and Penrod, 1984). Individuals' tendency to conform increases if the majority gives *unanimous* responses (Asch, 1956) and if the majority is composed of familiar peers instead of strangers (Asch, 1956; Bond and Smith, 1996). Finally adult individuals seem to conform more in *public* than when their response is anonymous (Allen, 1966; Bond, 2005).

### 2.2.1. Conformity in children

Most studies investigating conformity in children match the general structure of the original paradigm conceived by Asch (1956). One individual, with high level of performance on a certain task, is confronted with a majority of peers who unanimously give a false response. Individuals choose between sticking with their own judgement and abandoning it by adjusting their behaviour to the majority. Already around the same time as Asch conducted his experiments with adults, studies demonstrated conformity in children between the ages of 7 and 10 years (Berenda, 1950). More recent studies demonstrated children as young as 4 years of age conforming to a majority of adults (Corriveau and Harris, 2010). Other recent studies have found that 4 year old children also conform to a majority of same-age peers (Haun and Tomasello, 2011; Walker and Andrade, 1996).

Given the limited amount of available data, however, the picture emerging from studies on conformity in children is quite unkempt. In general, it seems fair to say that conformity in children appears to follow the same structure found in adult studies: similar to adults, children seem to conform more if the amount of noise relative to the signal in the stimulus is increased, resulting in a decrease of subjects' confidence in their own judgements (Hamm, 1970; Hoving et al., 1969), although not all studies find this effect (Iscoe and Williams, 1963; Iscoe et al., 1963). Also similar to adults, girls seem to conform more than boys (Costanzo and Shaw, 1966; Iscoe and Williams, 1963; Iscoe et al., 1964), which may already be true for children as young as 4 years of age (Haun and Tomasello, 2011). Not all studies, however, find differences in conformity between the sexes (Bishop and Beckman, 1971; Haun and Tomasello, 2011). Besides gender, other demographic variables seem to influence children's tendency to conform. Within the United States for example, a sample of Caucasian girls between 7 and 15 years of age conformed more than African American girls of similar age, while boys' behaviour did not vary across populations (Iscoe et al., 1964). Similarly, rural Mexican children between 7 and 9 years of age conformed more than their age-matched Anglo American counterparts (Kagan, 1974). In the latter case,

conformity positively correlated with a difference in cognitive style, i.e. individuals displaying high field-dependent cognitive style (tendency to analyse information relative to the surrounding contextual information) conformed more often than individuals with a field-independent cognitive style (tendency to process details separately from the surrounding context) (Witkin et al., 1977). Across ages, conformity on unambiguous tasks declines between the ages of 3 and 10 years (Bishop and Beckman, 1971; Cohen et al., 1973; Hamm, 1970; Hoving et al., 1969; Iscoe et al., 1964; Walker and Andrade, 1996). Studies using ambiguous tasks largely report a slight increase in conformity across the same developmental period (Costanzo and Shaw, 1966; Hamm and Hoving, 1969; Iscoe et al., 1963). In hypothetical situations in which peers urge the child to perform either anti-social, prosocial, or neutral behaviours, conformity increased until the age of 10 years, while declining shortly after (Berndt, 1979). The same and other studies compared conformity to peers and conformity to parents. The tendency to conform to peers' antisocial behaviour steadily increased with age, peaking in the teenage years. Conformity to the prosocial behaviour of peers did not vary with age. However, conformity to parents on both types of behaviour decreased steadily with age (Berndt, 1979; Bixenstine et al., 1976; Bronfenbrenner, 1967, 1970). Furthermore, the extent to which children conform to a majority appears to be susceptible to social feedback. When children between the ages of 6 and 14 years, after having adjusted their opinion to the majority in a classic conformity design, are confronted with objectively correct responses given by adult models, conformity decreases (Hamm, 1970). From at least 9 years of age children not only conform, but also expect other peers to conform (Killen et al., 2002).

### 2.2.2. Conformity in non-human animals

The results of the open diffusion studies in primates mentioned in Section 2.1.2 were generally interpreted in terms of conformity rather than majority-biased transmission (Bonnie et al., 2007; Dindo et al., 2009; Hopper et al., 2011; Whiten et al., 2005). In these open diffusion studies, individuals first acquired one strategy through the observation of conspecifics, after which some of them discovered an equally effective alternative strategy through individual exploration. Over time, the individuals that discovered the alternative tended to revert back to their first learned strategy – the only strategy that was seeded in the group and thus the most common strategy. This observation led the authors to argue for the existence of conformity in primates (see Claidière and Whiten, 2012). For several reasons, however, the observation that these primates tended to converge on one behavioural strategy does not necessarily indicate conformity. Besides the earlier mentioned limitations of the open diffusion design, it is unclear whether the individuals reverted back to the most common strategy under influence of a majority or whether the presence of a majority coincided with their normal, individual tendency to favour their first learned behaviour. Especially in the case of chimpanzees, persevering in the first acquired behaviour seems a reasonable alternative explanation given that they display a high level

of behavioural conservatism across several different contexts (Hrubesch et al., 2009; Marshall-Pescini and Whiten, 2008; Bonnie et al., 2012). Moreover, the ‘reversions’ to the most common behaviour do not test for conformity as defined above: rather than having to *change* their initially acquired behaviour in order to match the majority, the designated ‘conformists’ needed to *retain* their most familiar strategy (see van Leeuwen and Haun, *in press*).

The most compelling argument for the existence of conformity in animals comes from the aforementioned studies in sticklebacks, where both three-spined (Webster and Hart, 2006) and nine-spined sticklebacks (Pike and Laland, 2010) seem to give precedence to the majority strategy over their personal experience. In the former, sticklebacks tended to spend more time foraging at the food patch where the majority of demonstrators had been present compared to the food patch where the focal fish had experienced food in previous private sampling sessions (Webster and Hart, 2006). Elaborating on this design, Pike and Laland (2010) investigated several conditions with differently sized majorities, where they found that the focal sticklebacks were disproportionately inclined to forgo their personal preference in favour of the food patch demonstrated by the majority conditional on the increasing (relative) majority size (Pike and Laland, 2010). The same processes have also been studied in guppies, but unless the individuals were forced to choose between a costly option and copying the shoal’s behaviour, guppies stuck with their individually acquired knowledge (Kendal et al., 2004).

Studies in rats showed that individuals change their location preference after observing a conspecific model (Konopasky and Telegdy, 1977) and their food preference after smelling the breath of one or two conspecifics in succession, even to the extent of preferring unpalatable or presumably toxic food (Galef and Whiskin, 2008; Jolles et al., 2011). However, since no majority demonstrations were included in these studies, it remains to be investigated whether the preferences changed through the same mechanism(s) that might underlie majority influences.

In sum, the taxonomic distribution of conformity remains as of yet unclear. On the one hand, results seem to indicate that at least humans and sticklebacks share the tendency to adjust personal preferences to majority strategies, probably indicative of convergent evolutionary processes (Laland et al., 2011). On the other hand, studies have not yet been designed adequately to compare conformity across species.

Importantly, all instances of majority influence described thus far are defined by statistical behavioural outcomes, i.e. the likelihood of individuals to adopt the majority strategy with or without prior behavioural tendencies. Identifying the mechanisms behind the behavioural end-results will enable us to compare majority influence across ages and species with greater precision.

### 3. Mechanisms behind majority influence

After considering some of the existing evidence for majority influences in children and other animals, the question remains whether children and other animals

copy the majority strategy because they are biased towards copying what most other individuals are doing, or whether other mechanisms are involved that amount to the same end-result.

Most studies on majority influences aim to study the learning strategy ‘copy-the-majority’ (Laland, 2004), in other words, the bias to copy the majority *because it is* the majority. Formal models suggest that natural selection should favour a copy-the-majority strategy because it helps individuals to quickly adopt the locally adaptive behavioural variants, especially in a spatially variable environment with migration between subpopulations (Boyd and Richerson, 1985; Henrich and Boyd, 1998; Kameda and Nakanishi, 2002; Kandler and Laland, 2009; Wakano and Aoki, 2007). For this reason we would expect the copy-the-majority strategy to be present in many different social species across various families of social animals, including humans.

However, although assumed by many to be the fundamental underlying mechanism, majority-biased transmission does not necessarily imply a copy-the-majority strategy. An increased likelihood to end up with the behaviour of the majority can often also be explained by several alternative copying strategies. For example, random copying, i.e. a mechanism that does not take into account any contextual information, can result in majority-biased transmission: if observers copy an individual at random, the likelihood to copy a majority member exceeds that of copying a minority member. In consequence, the likelihood with which individuals copy the most common technique exceeds that of any other available alternative (Mesoudi, 2009; Mesoudi and Lycett, 2009).

Moreover, if copying is not random, majority-biased transmission can still come about through multiple alternative mechanisms other than ‘copy-the-majority’. For example, if we consider that the majority by definition encompasses most individuals in the group, the strategy used by most individuals and the strategy used most often are usually conflated. Similarly, the strategy used by most individuals and the strategy with the highest probability to be encountered first are conflated: the likelihood that the first ‘demonstrator’ an observer encounters is a majority member equals the size of the majority in the population, which by definition is larger than 0.5. Assuming that other model-characteristics such as prestige and skill distribute evenly across the population, the majority would also include most prestigious and most skilled individuals. As a result, several different social learning biases might underlie majority-biased transmission, such as the preference to copy what most individuals do, what the most prestigious individuals do (Chudek et al., 2012), what individuals do that are similar to the observer (Rosekrans, 1967), what the most skilled individuals do (Corriveau and Harris, 2009) or any combination thereof. The relative importance of these different factors might of course vary across species and ages, resulting in majority-biased transmission based on varying, equifinal compositions of underlying mechanisms.

One way to shed light on the mechanisms underlying majority influences is to observe whether the likelihood with which an individual might copy the majority strategy

is significantly larger than the relative size of the majority (*disproportionate* copying). If this is the case, at least random copying can be refuted as the underlying mechanism of the majority influence. Formal models of social learning call this scenario *conformist transmission* (Boyd and Richerson, 2009; Efferson et al., 2008; Eriksson et al., 2007; Henrich and Boyd, 1998). Conformist transmission has however rarely been shown in adults (recent absence of evidence: (Claidière et al., 2012; Coultas, 2004; Eriksson and Coultas, 2009); recent positive evidence: (Morgan et al., 2012)), and never in children (recent absence of evidence: (Haun et al., 2012; Whiten and Flynn, 2010; Corriveau and Harris, 2009)). Also, none of the aforementioned studies in primates reported a disproportionate tendency to copy the majority of group members, leaving open the possibility that chimpanzees only ever copy other individuals at random (Haun et al., 2012). However, the aforementioned studies in sticklebacks have shown that sticklebacks can match the foraging strategy demonstrated by the majority (Webster and Hart, 2006), even to the extent of disproportionate copying (Pike and Laland, 2010), providing the proof that conformist transmission exists in non-human animals (for a detailed recent review see Morgan and Laland, 2012).

However, while the presence of conformist transmission excludes random copying from the possible mechanisms that amount to majority-biased transmission, it does not necessarily indicate a copy-the-majority strategy. For reasons outlined above, alternative mechanisms such as copy-the-most-frequent strategy or copy-the-most-productive strategy might explain the behavioural end-results under a conformist transmission scenario. One of the aforementioned studies reporting on majority-biased transmission in children and chimpanzees attempted to shed light on the underlying mechanism. Haun et al. (2012) separated majority effects from frequency and order effects by varying the number of demonstrators and the number of demonstrations independently of each other, while controlling for order of demonstration (Haun et al., 2012). Two-year-old children and chimpanzees, but not orangutans, preferably copied the majority's solution to a novel task. Only the children also relied on the frequency of demonstrations when the number of individuals was equal across strategies. All three species in this study largely ignored the order of demonstration. It remains to be investigated whether observers value the order of demonstration when the number of individuals and the number of attempts are controlled for. More generally, it needs to be empirically investigated to what extent the majority of individuals afford other learning strategies than copy-the-majority. For instance, while the likelihood that individual characteristics that are predicted to be adaptive bases of attraction (e.g. prestige, skill; see Laland, 2004) are present in the majority is statistically higher than for any minority simply due to numbers, future studies should investigate the distribution of individual characteristics across the majority and minority of a population. Moreover, the even more complex interplay between genetic predispositions, environmental influences and cultural determinants poses a further intriguing challenge for the endeavour to

single out the mechanism involved in behavioural patterns like majority-biased transmission. One promising attempt at this endeavour is being made by researchers that are developing tools to recognize statistical signatures of cultural transmission within (non-human) animal populations (Boogert et al., 2008; Franz and Nunn, 2009; Hoppitt et al., 2010; Kendal et al., 2009; McElreath et al., 2005, 2008). Another fruitful perspective might be that of inter-individual differences (e.g. Efferson et al., 2008; McElreath et al., 2005). Where behavioural patterns are usually scrutinised on the population level, for reasons of adaptability, it is reasonable to assume that individuals differ in their learning capacities as well as their learning preferences. For instance, in the case of social learning preferences, individuals can, over a multitude of different situations, be described along a continuum with dedicated conformists at one end of the scale and independent mavericks at the other (see Efferson et al., 2008). Integrating this perspective in studies exploring the mechanisms by which individuals navigate through their (social) environments might be helpful in the cross-species and cross-age comparison of majority influences.

Related to the endeavour to identify the responsible *mechanism* for majority-biased transmission across species is the investigation of the different *motivations* that could instigate certain mechanisms. Especially copy-the-majority, the tendency to copy the majority because it is the majority, has sparked both theoretical and empirical investigations into the potential suite of different individual motivations, especially in cases where individuals abandon their behavioural tendencies and convictions in favour of the majority position (conformity). In the next section, we will review the extent to which empirical data sheds light on the motivational component of the copy-the-majority mechanism and indicate further ways to understand the existence and ontogeny of majority influences in general.

#### 4. Motivations behind majority influence

Social psychologists discuss two interacting motivations resulting in copy-the-majority, especially when it results in conformity (Deutsch and Gerard, 1955): behavioural optimisation (*informational conformity*) and social strategising (*normative conformity*). Informational conformity describes the motivation to adopt a majority position because it is taken to be a reliable source of information about a shared objective reality. There might often be good reasons to trust the majority over oneself: albeit not necessarily the best available option, the strategy adopted by most individuals is an aggregate of individual learning outcomes and thus likely – if many converge on the same strategy – relatively safe, reliable and productive. Formal models support this idea by showing that adopting the majority behaviour is an effective strategy at least in spatially variable environments with migration between subpopulations, since it accelerates the acquisition of locally adaptive behaviour (Boyd and Richerson, 1985; Henrich and Boyd, 1998). Normative conformity describes the motivation to adopt a majority position because of the social benefits of conforming relative to dissenting (Haun and Over, *in press*).

Due to this motivational heterogeneity, the same level of conformity across ages, sexes, populations or species might be based on different compositions of underlying motivations. Experiments have tried to distinguish the relative contribution of informational and normative motivations by varying the privacy of the participants while giving their response. The idea behind this manipulation is that normative conformity will often be driven by the sake of public appearance alone (public conformity), while informational conformity often results in a genuine, socially mediated change in attitudes and/or perception (private conformity). Some reports in adults (Asch, 1956) as well as preschool children (Haun and Tomasello, 2011) found lower rates of conformity if participants, after being exposed to the majority opinion, responded only in the presence of the experimenter, but not the majority. The authors of these studies concluded that the reduction of conformity in the absence of a social consequence demonstrated a partial contribution of normative motivations on trials during which participants responded in public. A large meta-analysis, however, found no reliable correlation between the privacy of responses and the level of conformity across studies (Bond and Smith, 1996). It therefore, as of today, remains challenging to convincingly identify the composition of motivations underlying conformity using behavioural experimentation only, making interpretations of similarities and differences across species, sexes, cultures and ages rather difficult to substantiate (Cialdini and Goldstein, 2004; David and Turner, 2001; Wood, 2000).

#### 4.1. Can physiological measures differentiate between different motivations to conform?

The use of physiological measures in experimental designs may provide additional information about types of conformity and the underlying motivations (Bogdonoff et al., 1962; Mojzisch and Krug, 2008). Recent functional magnetic resonance imaging (fMRI) studies investigating conformity have produced variable results depending on the task involved. One group of studies explored the effect of social influences on subjective ratings of consumer items (Campbell-Meiklejohn et al., 2010), faces (Klucharev et al., 2009; Zaki et al., 2011) and abstract symbols (Mason et al., 2009). These studies found that social pressure altered brain activations in regions previously associated with assessment of subjective value (e.g. the ventral striatum and orbitofrontal cortex). These results led to the assertion that social pressure can change the subjective value originally associated with the items (Zaki et al., 2011). However, social pressure seems to exert more effects; two studies that used conformity paradigms outside the subjective valuation domain indicated that conformity affects other regions depending on the specific task requirements. For example, Berns et al. (2005) used a conformity protocol in the context of a mental rotation task and found that conformity affected the occipito-parietal network usually found to be involved in mental rotation tasks. Edelson et al. (2011) demonstrated that conformity in memory is subserved by activation in the hippocampal complex, a critical region for memory processing. In summary, conformity induced

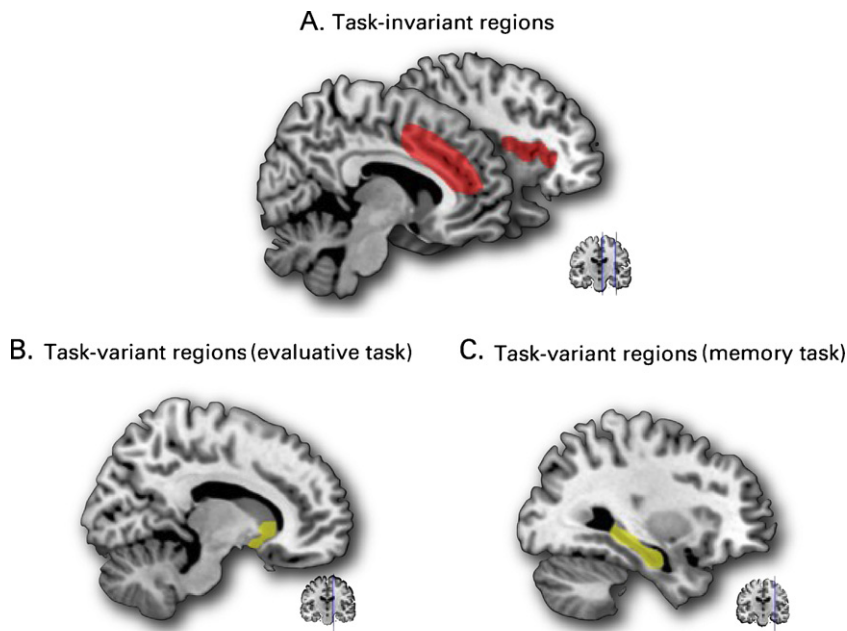
alterations in behaviour correspond to measurable changes in brain activity in task specific regions.

Although different conformity paradigms produce different neurophysiological effects, there appear to be areas of commonality among various experiments. For example, in response to social information conflicting with personal beliefs, enhanced brain activity has frequently been observed in posterior medial frontal regions and the insula (Berns et al., 2010; Campbell-Meiklejohn et al., 2010; Edelson et al., 2011; Klucharev et al., 2009). The medial frontal regions were primarily found in the dorsal anterior cingulate cortex and surrounding areas, which are considered to be involved in processes including tracking decision uncertainty, conflict monitoring and adaptive goal directed behaviour (Botvinick et al., 2004; Campbell-Meiklejohn et al., 2010; Falk et al., 2010; Klucharev et al., 2009). Anterior insula activation has been proposed to subserve a variety of processes including response to aversive/negative events, theory of mind, and interoception (Critchley et al., 2004; Gallese et al., 2004; Krolak-Salmon et al., 2003). More specifically, regarding social norms, insula and dorsal anterior cingulate activity have been proposed to model degrees of discrepancy between group norms and personal beliefs in a fashion akin to a prediction error, which may then lead to subsequent behavioural adjustments (Klucharev et al., 2009; Montague and Lohrenz, 2007).

Based on the aforementioned studies we suggest a two-phase model for conformity effects in the brain (Fig. 1).

- (1) Regardless of the specifics of a given task, confrontation with external pressures, which contradict internal conceptions, results in increased brain activation in *task invariant regions* (Fig. 1A) such as the dorsal anterior cingulate and the anterior insula. Activation in these regions probably corresponds to task independent factors (e.g. subjective degree of conflict, aversion, or mental perspective taking) and correlates with the size of discrepancy experienced by the individual.
- (2) Activity in *task invariant regions* may provide brain sub-systems involved in a specific task (i.e. *task variant regions*, Fig. 1B and C) with a signal indicating the need for a behavioural adjustment. Changes in these sub-systems will then generate the behavioural manifestation of conformity in the given task. Activations here need not be mutually exclusive; for example, a change in memory may involve a change in subjective value (and vice versa).

Importantly, given the temporal resolution limitations of fMRI, more research is needed to determine this proposed causal relationship between *task invariant* and *task variant regions*. One innovative approach used by Klucharev et al. (2011), is to employ trans-magnetic stimulation to deactivate the postulated *task invariant region* of the posterior medial frontal cortex. They found that deactivation of this region reduced levels of behavioural conformity regarding face attractiveness valuations. In a complementary approach Campbell-Meiklejohn et al. (2012) used a pharmacological intervention that has been demonstrated to enhance dopaminergic activity in task specific regions of



**Fig. 1.** (A) Illustrative example of two proposed task invariant regions showing general conformity related activity: the cingulate cortex (front panel) and the anterior insula (back panel). (B and C) illustrative examples of two task variant sub-systems; the ventral striatum for evaluative tasks (B), and the hippocampus for memory tasks (C). Activations in these sub-systems need not be mutually exclusive. The diminutive panels on A, B and C illustrate the corresponding slices in a coronal view.

valuation (e.g. ventral striatum) (Volkow et al., 2001). This resulted in higher levels of conformity following moderate social conflict. Combining these approaches with fMRI may provide insight into the function and relationship of task variant and task invariant regions.

Several neuroimaging studies have tried to distinguish between conformity leading to mere compliance (*public conformity*) and conformity leading to actual changes in beliefs (*private conformity*). This distinction is related to the underlying motivations for conformity since informational conformity is posited to lead to more instances of private change whereas normative conformity to relatively more instances of compliance (Smith and Mackie, 2007).

Under the assumption that a private change in value judgements will induce a corresponding and measurable change in activity of brain circuits associated with subjective valuation (Campbell-Meiklejohn et al., 2010; Zaki et al., 2011), one fruitful approach would be to investigate brain activation in areas associated with subjective value (Campbell-Meiklejohn et al., 2010; Zaki et al., 2011). By contrast, *public conformity* will less likely alter personal valuations and will thus not result in such changes (Berns et al., 2010). A different approach, taken by Edelson et al. (2011), is to directly compare brain activation during conformity events that led to behavioural compliance only vs. conformity events that led to actual changes in memory. Consistent with our model (Fig. 1), the differences found so far between conformity types were not found in the regions associated with general *task invariant* processes but rather in the *task variant* sub-systems. Activity in *task invariant regions* in both *public* and *private conformity* appears to show sensitivity to general factors such as the degree of dissonance between individual and

group opinions. In contradistinction, when brain activity modulations are observed in the *task variant regions*, this seems to indicate that private change has occurred in this domain. For example, activation changes in regions associated with memory may indicate a change in private memory representations and changes in regions associated with processing of value might indicate a change in subjective valuation.

It is not clear however to what extent such activations are unique to influence engendered by a social source. Three studies directly compared the influence of information delivered via an interpersonal source to the same information delivered via a non-social source (i.e. a computer). Two studies (Berns et al., 2005; Klucharev et al., 2009) found that activations in regions involved in social conformity were weaker if the source of influence was non-social. This was taken as an indication that social and non-social influences activate the same brain networks and differ quantitatively rather than qualitatively (Klucharev et al., 2009). A third study compared differences between social and non-social influences resulting in *private* conformity (Edelson et al., 2011). Here, the researchers found that although social and non-social influences indeed elicited activations in common regions, social influences that induced long-lasting conformity had unique brain correlates (e.g. heightened amygdala-hippocampal connectivity) when compared to corresponding long-term changes induced by non-social information (Edelson et al., 2011).

It seems from this preliminary evidence that social and non-social influences share at least some brain networks, whereas other areas of activation are unique. This view is in line with evidence that learning from a social source



relies, at least in part, on systems that are used in learning from non-social sources (Behrens et al., 2008), but may also have additional distinct brain mechanisms (Adolphs, 2006; Burke et al., 2010).

### 5. Majority influence in children and other animals: concluding remarks

Considering the current state of the empirical evidence it seems fair to say that several animal species, including human children, are in one way or another subject to majority influences. Studies in children and other animals are, however, difficult to integrate for three reasons: (i) majority influences have not been operationalised commensurably. To understand how majority influence might be different in humans from that of other species, study designs need to be calibrated across species; (ii) many studies convolute behavioural end-results with the underlying mechanisms; (iii) while human studies have started to investigate the proximate motivations underlying majority influence, especially conformity, animal studies have not yet done so.

For now, the growing body of evidence seems to indicate that majority-biased transmission exists across species, ranging from human children to fruit-flies. Researchers have started a promising effort to identify compositions of mechanisms behind majority influence across species, ages and scenarios and we hope that this review will help push this field of investigation forward. Conformity has thus far only been shown in humans and sticklebacks, where only humans have shown to conform due to both informational and normative motivations. The lack of information on conformity tendencies in other species is however responsible for this preliminary conclusion; with this review we hope to encourage researchers to study conformity in animals more commensurably. The underlying motivations have only rarely been studied in children and never in other animals. However, we might well find the most interesting differences across ages and species in the underlying motivations. To put it in more stark terms, species differences, as well as differences across human children of different ages will not be fully understood without tracking the underlying mechanistic and motivational composition driving majority influence. Cognitive Neuroscience might provide methodological tools that will supplement prior efforts to track the motivational state underlying children's and adults' conformist behaviour. In this way the combination of clear conceptual distinctions, detailed behavioural paradigms and additional physiological measures should allow us to understand the ontogeny and phylogeny of majority influences.

### Conflict of interest statement

We declare no competing interests.

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