Is there heightened sensitivity to social reward in adolescence?

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Abstract

During adolescence, individuals are particularly susceptible to social influence. One explanation for this is that social stimuli have a heightened reward value at this age. To date, most evidence for heightened social reward in adolescence is found in the animal literature. Human adolescents show increased activation in fronto-striatal brain regions to rewarding social stimuli, but also to negative social stimuli, suggesting that adolescence may be a period of hypersensitivity to all social stimuli. Additional evidence from humans and animals suggest that the presence of others may heighten the value of non-social rewards; these findings should be incorporated into theories of social reward in adolescence.

Highlights

- Adolescence may be a period of heightened sensitivity to social reward
- Playing with a conspecific is more rewarding for adolescent than for adult rats
- Human adolescents show hypersensitivity to both positive and negative social stimuli
- For both humans and rodents, presence of peers may increase value of other rewards

Introduction

Adolescence, the period of life between puberty and adult independence, is a key stage of social development across species [1,2]. During adolescence, individuals experience a period of 'social reorientation', during which they spend less time with their parents and more time with same-age peers [3,4,5]. Adolescence is also a period of heightened susceptibility to social influence. For example, in a study examining peer influence on risk perception, young adolescents were more influenced by the opinions of their same-aged peers than the opinions of adults, while children and adults were more influenced by adults' opinions about risk [5; see Figure 1]. Adolescents are also more likely than adults to engage in risky behaviours around peers [7–10]. One possible explanation for this increased level of social influence is that the reward value of social interactions – in particular, of gaining social approval – is heightened in adolescence, and this sensitivity to social reward leads individuals to engage is more risky behaviours to win the approval of their peers [1,11,12]. Here, we review recent evidence that social approval and other social interactions have particularly high reward value in adolescence.

Social reward in adolescent rats

Playing with conspecifics is a highly rewarding behaviour for many mammals. Research with rats has shown that the amount of time spent playing tends to peak in adolescence and decline thereafter (e.g. [5] [14]; See Figure 2), and that this behaviour may have more reward value for adolescent rats than it does for adults. Conditioned place preference paradigms, in which one compartment is associated with social interaction and the time spent in that compartment is compared with time spent in

other compartments, demonstrate that the opportunity to play with another animal is more rewarding for adolescent rats than it is for adults (e.g. [15]). One study found that a preference for a social compartment over an amphetamine compartment developed in adolescent rats who had spent the past seven days in social isolation, while adolescents who had not experienced social isolation did not show a preference for either compartment [16]. In contrast, adult rats did not show a preference for either compartment, regardless of whether or not they had experienced social isolation [16]. In addition, a brief interaction with another animal induces a more sustained release of dopamine in adolescent rats than in adult rats, suggesting a diminished habituation to rewarding stimuli in adolescents [17]. Together this evidence suggests that, at least in rats, social interactions may have a greater reward value for adolescents than for adults. However, few studies have investigated the reward value of social interactions in prepubescent rats, which is critical to understanding whether social reward value peaks in adolescence.

Social reward in human adolescence

In humans, the empirical evidence that adolescence is a heightened period of social reward is mixed. A primary limitation in the literature is that very few studies have compared social reward in children, adolescents and adults in a single study, making it difficult to assess the hypothesis that social reward value is temporarily heightened in adolescence. Some studies have found that, compared with children, adolescents spend more time with their peers, and report more positive affect from this activity [15,16]. However, this finding is dependent on gender and culture [18-20]. Experimental studies assessing social reward in human adolescents suggest that the

reward value of social stimuli may be similar for children and adolescents. Positive social stimuli - a series of cartoons depicting one person giving another person a compliment and a thumbs up gesture - were rated as likeable by 8-16 year olds (no data was available on any associations between age and likeability ratings; [21]). Increasing the magnitude of the compliment (for example, low magnitude: 'OK!'; high magnitude: 'You're a champion!') improved reaction time and accuracy similarly in both children (8-11y) and adolescents (12-16y; [21]). A second study found that, in a sample of 8-25 year olds, there was no association between age and likeability ratings of peers who gave positive social feedback [22]. These findings suggest that subjective and behavioural responses to social rewards may not differ significantly between childhood and adolescence [21].

Studies comparing human adolescents to adults are limited, but the evidence to date suggests that socially rewarding stimuli may be processed differently in human adolescents compared with adults. One study found that distracting smiling faces impaired performance on an n-back working memory task when the emotional expression was irrelevant (when gender was the target) in adolescents (12-14 year olds) but not in adults (18-29; [23]). One possible explanation for this is that these symbols of social approval are particularly rewarding in adolescence and therefore more distracting [23]. Alternatively, it may be that others' emotional expressions are more distracting for adolescents because these stimuli are more salient at this age. In other words, social signals may be particularly important and attention-grabbing because this is a period of rapid social development [4,23], without necessarily

increasing in hedonic value. Further studies are needed that assess whether any altered behavioural responses to faces and other social stimuli are due to a temporary increase in subjective value of positive social stimuli in adolescence or due to a general heightened sensitivity to social stimuli at this age [24]. Critically, these studies should be conducted with children, adolescents and adults to determine whether behavioural response to social reward undergoes a non-linear developmental trajectory, with a peak in adolescence.

Neural response to social reward in human adolescents

Neuroimaging studies have tended to demonstrate that adolescence is a period of heightened reactivity to all social stimuli, and not just to social reward. Rewarding stimuli typically activate a network of brain regions including the ventral striatum (VS), medial prefrontal cortex (MPFC) and orbitofrontal cortex (OFC; [25]). Neuroimaging studies in adults have consistently demonstrated activation in these areas in response to positive social stimuli or scenarios, such as receiving social approval [26]. BOLD signal in these regions was exaggerated in adolescents, compared with adults, in a go/no-go task that used happy faces as appetitive cues [27]. Compared with children (6-12 year olds) and adults (18-29), adolescents (13-17) showed poorer impulse control to happy faces, as indicated by false alarms (erroneous presses) in no-go trials, and increased activation in the VS to happy faces relative to calm faces (collapsed across go and no-go trials; [27]). However, a second study showed similar findings when the facial expression was fear [28]. Compared with adults (>18 years old) and children (6-12), adolescents (13-17) made more errors and showed increased

activation in the OFC and MPFC when viewing fearful relative to neutral faces (VS activation showed the same pattern but did not survive correction for multiple comparisons; [28]). Similarly, a longitudinal study that assessed participants at age 10 and age 13 found that there was an increase in VS and VMPFC activity between the two time points when participants passively viewed both happy and sad faces [29]. These studies suggest that adolescence is a time of neural hyper-responsiveness to both positive and negative social stimuli, and not exclusively to social reward.

The importance of subjective value ratings

Evidence of increased activation in 'reward-related' brain regions alone is insufficient to conclude that stimuli are being experienced as rewarding, because these regions are activated to both positive and negative stimuli and possibly involved in other cognitive processes in addition to reward [30]. For example, the VS signals salient information of both positive and negative valence, rather than exclusively the reward value of positive stimuli [30], and is active during the anticipation of both social approval and rejection in adults [31]. The heightened activation in this region to both positive and negative social stimuli in adolescence suggests that region is more active during this period of life to social information in general, rather than specifically an increase in reward value of positive social stimuli or interactions [32,33]. This is in line with evidence that adolescents are also more sensitive to social exclusion – a negative social experience - than adults are (e.g. [34]). However, such conclusions cannot be drawn from fMRI data alone because of the problem of reverse inference [34], and further studies are required that assess the subjective experience of social reward and

social exclusion/punishment in all age groups (e.g. [35]). The existing evidence does not preclude the possibility that social approval has a heightened reward value for adolescents compared with children or adults, but comparisons of subjective value ratings across all age groups are needed to confirm this.

The presence of peers may enhance the value of other rewards

A related hypothesis is that the presence of peers may create an environment in which *other* rewarding stimuli take on an increased reward value, and that this effect is enhanced is adolescence [9,37,38]. In support of this, it is well documented that adolescents engage in more reward-seeking behaviours when with friends compared to when they are alone. For example, in a simulated driving game, adolescents took significantly more risks in the presence of peers than when they are alone, whilst adults did not [7–9]. In addition, adolescents smoke more and drink more alcohol in the presence of peers [10]. It has been proposed that this phenomenon is due to the enhanced importance of social approval and rejection during adolescence in humans. However, a recent study found that adolescent mice also consume more alcohol in the presence of conspecifics than when they are alone, while adult mice do not [38], suggesting that the presence of peers may not solely influence adolescents' behaviour by means of higher order cognitions such as the importance of social approval. Other mechanisms – such as the presence of peers enhancing the reward value of *other* stimuli (e.g. alcohol, drugs) – may also contribute [9,34,38]. The mechanisms behind this phenomenon are unclear, and should be explored in future studies to better

understand why the presence of peers affects behaviour towards rewarding activities and stimuli.

Conclusions

During adolescence, individuals spend more time with peers and are more influenced by their opinions and behaviours (e.g. [6]). One possible explanation for this is that the reward value of spending time with peers and gaining their approval temporarily increases during this period of life (e.g. [1]). The empirical evidence to date precludes this conclusion, however, and suggests a more complex picture of social reward in adolescence. First, studies in rats indicate that social interactions have greater reward value for adolescents than adults (e.g. [16]); additional studies comparing subjective ratings across age groups are required before the same conclusion can be drawn for human populations. Second, existing evidence indicates that human adolescents find potential social evaluation of either valence more salient than other ages [27,28], suggesting that both social reward and social punishment are more important at this time. Finally, evidence from both humans and mice suggest there may be a related phenomenon in adolescence: peers may prime an environment in which *other* rewards increase in value [37,38]. Together, these findings highlight the need for further studies (see Figure 3), including those using subjective ratings in humans, to fully understand the role that reward value plays in the cross-species phenomenon of social influence in adolescence.

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