**Social Cognition in Adolescents – The role of Mentalizing in risky decision-making in the social context**

**Introduction**

Humans make decisions based on their expected consequences, which is learnt from trial and error (Devaine et al., 2014). According to neuroeconomics, decisions are categorized under uncertainty and risk (Glimcher & Fehr, 2014) where risk refers to situations where the decision-maker knows with certainty the mathematical probabilities of possible outcomes of choice alternatives and uncertainty refers to situations where the likelihood of different outcomes cannot be expressed with any mathematical precision. Furthermore, decision-making has been associated with social cognitive abilities (Zhang et al., 2017).

However, when decision-making involves predicting other peoples' overt reactions, humans almost irrepressibly engage in rich and complex representations of the other person’s hidden mental states. This insight to acquire the mental state of the other person, which is known as "mentalizing”, is developed during early childhood (Onishi & Baillargeon, 2005). Mentalizing is concerned with the interpretation of social signals, from eye gazes and facial expressions to overt behaviour and language, which is why it lies at the core of human social cognition (Devaine et al., 2014). However, current research falls short of an understanding of the computational mechanisms underlying mentalizing, or of a clear demonstration of its added value for decision making in social exchanges (Frith & Frith, 2012). On the other hand, it has been shown that decisions made in the context of economic games entail recursive thinking (Camerer & Chong, 2004). This is essential because if others' reward depends upon your action, what they believe you will do is relevant for you to predict their behaviour.

In the present study, I intend to analyze the neural mechanisms of mentalization underlying risky decision-making in the adolescent brain. According to Rodrigo et al. (2014), the lifespan of adolescence begins around the time of physical puberty and ends with the assumption of adult-like levels of autonomy. Adolescence is characterized by making risky decisions. Relative to childhood, adolescents are faced with more frequent and complex demands on independent decision-making. Adolescents spend more time unmonitored by guardians and have growing access to risky and ambiguous situations that involve potential adverse outcomes such as access to illegal substances, opportunities to take physical and sexual risks, and complex peer-related decisions that could impact their social status. It is thus vital to understand the neurocognitive processes that underlie decision-making in adolescence in a social context.

To test these ideas, the study hypothesis that.

1. Mentalizing network activated in adolescent brain during uncertain decision-making is different from risky decision-making in a social context.
2. The task complexity increases the activation of the mentalizing neural circuit in adolescents during risky social decision-making.
3. Female adolescents have increased activation of the mentalizing network compared to male adolescent while taking risky decision-making in a social context.

**Literature Review**

In recent years, [Chein et al. (2011)](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3924553/#B16) examined the impact of the presence of peers on risky decision-making in a driving game ([Gardner and Steinberg, 2005](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3924553/#B30)) for adolescents. The presence of familiar peers heightened responses in the ventral striatum (VS) and orbitofrontal cortex (OFC) during risk choices more for adolescents than adults. Adolescents less strongly recruited brain areas associated with cognitive control like dorsolateral prefrontal cortex (DLPFC) than adults, and brain activity in this area did not vary with peer manipulation. However, a different pattern of results emerged in a second study done by [Peake et al. (2013)](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3924553/#B49) using the same task. Adolescents’ safe choices in the driving game, after an episode of social exclusion from hypothetical peers, were associated with greater activation in right dlPFC and orbitofrontal cortex (OFC), but also with other regions implicated in “Theory of Mind” abilities such as the posterior cingulate cortex and precuneus (PCC/prec), medial PFC, and bilateral temporoparietal junction (TPJ). Since both these studies give mixed results in the activation of brain regions, the present study intends to compare and analyze the activation of brain regions associated with mentalizing in adolescents during uncertain and risky decision-making in a social context with their peer.

Risky decisions, and to some extent, gender and social aspects, have been a recent focus of behavioural and neural assessments. At the behavioural level, and considering interpersonal differences, studies have found that females are consistently shown to be more risk averting compared to males (Galván et al., 2013), especially among adolescents (Cazzell et al., 2012, Lee et al., 2009, Lighthall et al., 2011). Previous studies, most often using fMRI or EEG, have identified several brain areas activated during the risky decision tasks (Bechara et al., 2003, Samanez-Larkin and Knutson, 2015, Saxe, 2006). Here as well, research does indicate potential male and female differences. Although those individuals identifying as males and as females show activations in the distinctive common neural network, different studies have yielded differing results. Some studies have indicated that males have a more robust overall top-down emotional (OFC) and cognitive (dlPFC) control over emotional events than females (Van, Homberg, & De, 2013).

On the other hand, researchers have also indicated that the OFC may show higher activations in female participants than in males. They suggest that this area may play a more important role in females' risky choice (Lee et al., 2009; Mcrae et al., 2008). Analysis of PET scan data has also shown that females activated the left dlPFC more strongly than males in the Iowa Gambling Task (Bolla et al., 2004). However, laboratory decision-making tasks do not consistently confirm the latter claim. Hence the present study investigates whether there are differences in neural activation between gender groups during risky decision-making in the social context.

Besides, although these studies have provided both a critical empirical basis and behavioural/neural results, they also contain design issues, which limit our full understanding of this topic. Mainly previous neuroscience studies have been conducted primarily in a single or in a "pseudo-two-person" situation, where solitary participants interact with a computer or another person via monitor/network. This limits the social context or face-to-face interactions that may modulate risk-taking in many human acts. This may also especially be responsible for the different risky decision task results, which may stem from different paradigms or levels of social interaction itself.

**Methodologies**

**a. Participants**

I would like to recruit 120 healthy adolescents, where 60 identified as male and 60 identified as females from an age range of 16 to19. They must have good vision as well as they must not have any neurodevelopmental disorders. These participants can be contacted through informing the nearby schools and universities with the consent note from parents of minor adolescents.

**b. Method**

The study prefers to use three experiments to analyze the neural network of mentalization during decision-making.

1. Uncertain decision-making \_ Playing Ludo game between the pair.
2. Risky decision-making – 2-card poker stud game will be used to analyze the risk-seeking or risk averting nature of the player.
3. Risky decision-making (Task Complexity) – 5-card poker stud game will be played between the pairs.

**c. Technique**

The study plans to use functional near-infrared spectroscopy (fNIRS) hyper scanning technique, which enables simultaneous measurement of brain activations of two individuals in realistic face-to-face social interactions (Liu & Pelowski, 2014a). This would help to analyze the interpersonal neural mechanisms underlying risky decision-making.

The advantages of fNIRS are noninvasiveness, low-cost modalities, perfect safety, high temporal resolution, full compatibility with other imaging modalities, and multiple hemodynamic biomarkers. Based on the exploration of hemodynamic signals, in the same way as functional magnetic resonance imaging (fMRI), and its blood oxygen level-dependent signal, fNIRS provides information on the functionally evoked changes in cortical oxyhemoglobin (HBO) and deoxyhemoglobin (HHb) concentrations with a relatively low spatial resolution (Pinti et al., 2019). However, its limitations are low brain sensitivity, low spatial resolution, and shallow penetration depth.

**d. Analysis**

The actions of the “follower” are classified as risk-seeking or risk averting based upon the combination of bet and call actions between the banker and the follower in the betting game.

To examine the decision-making behaviours, as well as the effect of gender, a repeated measure two-way ANOVA (Gender, 2 (male, female) x Behaviour-type, 3 (risk-seeking, risk averting, neutral)) could be conducted using Statistical Package for the Social Sciences (SPSS).

**Conclusion**

Humans constantly make decisions to obtain a benefit or to avoid loss. Safe choices typically have a higher probability of gaining a reward, but the reward value is relatively lower. Risky choices have a lower reward probability but a larger reward itself (Krain et al., 2006). Recently, such risky decisions have attracted increasing attention in the field of social neuroscience regarding the question of how information is used and a decision made at the level of interacting brains in natural social contexts. Embracing the multi-brain frame (Hasson et al., 2012), this study aimed to examine the question of how our brains might integrate cognitive processes as well as risky decision behaviour across two persons. Relatedly, are there behavioural and underlying neurobiology-related interpersonal differences such as a gender effect?

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