Cognition and Emotion: effective intuitive decision making

Melvin R. Roest (1914588)

m.r.roest@student.vu.nl

VU University Amsterdam

Faculty of Psychology and Education

Supervised by J.C. van Hooff

Abstract

The question of what constitutes effective intuitive decision making will be answered through means of a literature review. This question will be answered via the perspectives of psychology and neuroscience. It appears that: a high validity environment, a high amount of practice and a high interoceptive awareness are fundamental to intuitive effective decission making. From a neuroscientific perspective, the development of intuition (and expertise) results in a changed brain compared to non-experts. Certain brain areas change and integrate more with the default mode network compared to non-experts. The conclusive claim that the brain changes will be discussed. With regards to future research, it was observed that no paper reported the concept of game tree complexity. This concept could be vital in advancing the research design in the field of intuition and games. Hence the discussion of future research focuses on the concept of game tree complexity by calculating the most important games of the surveyed literature.

Cognition and Emotion: effective intuitive decision making

Introduction

Imagine a physics professor who has trained himself in physics in the undergraduate level (3 years), the graduate level (2 years), the PhD level (4 years) and accumulated a few years of work experience after that as a postdoctoral fellow. In the present day, he receives an undergraduate physics problem and needs to solve it in 30 minutes. Unfortunately he is not able to succeed. It might be that this is due to bad luck, that for some reason he cannot think of the solution. People have bad days in their life after all. However, it is not bad luck. A study showed that all physics professors (twenty) who were asked about the problem, were incapable of solving it. They could not solve an undergraduate physics problem that was counterintuitive, whereas a standard undergraduate physics problem was easily solved (Singh, 2002).

This story exemplifies the societal importance of effective intuitive (expert) decision making. This review is written to present some insight into what consitutes effective intuitive decisison making. To answer this question, the following sub-questions will be answered. (1) Does the environment matter in order to cultivate effective intuitive decision making? (2) Does expertise in a topic matter in order to cultivate effective intuitive decision making? (3) What role does interoceptive awareness play in intuitive decision making? (4) What are the neural correlates and (relevant) brain anatomy of expert (chess players their) intuitive decisions?

The first three questions are based upon a study that tried to answer the same main question (Dane & Pratt, 2007). Dane and Pratt (2007) suggested that the first two questions are a necessary condition for intuitive development, and that the third question is a necessary condition for an even better intuitive development. By answering those questions it will be explained how this could be the case. The fourth question was added, because it is the only question that aims to answer the process of intuition from a neuroscientific perspective.

Defining intuition

Before those topics are presented it is important to understand what effective intuitive decision making is. It the definition of Simon (1992) that this paper will follow: "The situation has provided a cue: This cue has given the expert access to information stored in memory, and the information provides the answer. Intuition is nothing more and nothing less than recognition" (as cited in Kahneman & Klein, 2009, p. 520). This definition also received some empirical support by looking at the neural organization of perception in chess experts (Krawczyk, Boggan, McClelland, & Bartlett, 2011).

Since the use of intuition could be beneficial to effective decision making, this term is defined as well. Effective decision making means that a person is able to know when to use intuition and when to use rational thinking (also called deliberative thinking), and handles a situation well. Sometimes it is better to use one of the two thinking modes or to combine them (Kahneman & Klein, 2009).

An example of a model that combines them is the recognition-primed-decision model. In this theory of intuition a person conjures a single course of action (through intuition), and refines this if she notices the course of action is inherently flawed (through deliberative thinking). It is one of the theories that the Naturalistic Decision Making (NDM) perspective on intuition promotes.

The NDM perspective focuses on the successes of intuition. There is also another perspective on intuition, the Heuristic and Biases (HB) perspective (Kahneman & Klein, 2009), which tends to be a more sceptical perspective than NDM. In this paper, the focus will be mainly on the NDM perspective.

1. Intuition and environment

According to Kahneman and Klein (2009) a practitioner should use her intuition on a topic that should not be too predictable or too unpredictable. If it is too unpredictable no reliable intuitive inferences can be made. If an environment has an extreme high validity, then computers are better at decision making than humans (e.g. Deep Blue the chess computer).

Kahneman and Klein (2009) describe that a high validity environment means that an environment has a high statistical structure (e.g. poker) or a high causal structure (e.g. chess), or both. However, on the other hand a low validity environment is an environment which is almost not predictable at all (e.g. approval of personal loans). This happens when there are phenomenon in the environment that are a very rare occurrence, to such an extent that it is not possible to draw correct intuitive inferences from these type of situations.

So to conclude the question: “does the environment matter in order to cultivate effective intuitive decision making?” The answer is yes it does. The environment should not be of too low validity.

2. Intuition and expertise

Kahneman and Klein (2009) had another criterium in their paper that was presented as a necessary requirement for effective intuitive decision making. A practitioner should invest a lot of time in understanding the topic of interest. According to them, it is estimated that in order to become a chess master 10,000 hours must be invested at the very least in understanding the intricacies of chess. Although it is a very crude estimate (Simon & Chase, 1973).

There is an addition to this view. The experiment of Singh (2002) showed that professors of physics could successfully solve the problem with intuition and deliberation when the rules of physics were applied in an obvious way. They failed to solve the counterintuitive problem. The only way to possibly solve the counterintuitive problem was through extensive long deliberation.

So to conclude the question: “does expertise in a topic matter in order to cultivate effective intuitive decision making?” The answer is, yes it does, but it is likely that expertise only remains in the realm of what is intuitive (i.e. activities that are practiced a lot), and it is outside of the realm of what is counterintuitive. This also applies if it is in the subject their own domain of expertise, which researchers view as a paradox. The identification of such a paradoxical problem is quite trivial; the problem must be solved in a way that has not been practiced (Singh, 2002).

3. Feeling Intuition

Damasio, Everitt, and Bishop (1996) reported that people who have lesions in their ventromedial prefrontal cortex (VMPFC) have problems with emotions and feelings in situations in which they would be expected to occur (e.g. happiness upon receiving a graduate degree). Because of this they hypothesized that muscoskeletal, visceral and internal milieu changes (called the body loop) or the anticipation of these changes (called the as if body loop) in the body can help an individual make complex decisions in a few seconds. When a person is conscious of this process (e.g. a good feeling in the body), then this new state act as an incentive or punishment signal. However, when a person is not conscious of this process, then this new state act as a biasing signal (e.g. an optimistic gambler). As an aside, if this is the case, then the perspectives between NDM and HB perspectives are more neurologically clear as well (Kahneman & Klein, 2009), since the diffference between them is a human being conscious or not being conscious of this process. This process takes previous experience into account and is supposed to work via the VMPFC. The VMPFC is supposed to store links between images of sound, vision or a fact and link it to a bodily state. This is what they call the somatic marker hypothesis (SMH). Ohira (2010) showed some more support for this hypothesis and hypothesized that psychopathic individuals show more rational decision making, probably because their bodily responses and emotions are impaired.

Based on the SMH, Dunn et al. (2010) researched what kind of effect interoception (operationalized as participants detecting their own heartbeat) has on intuitive decision making. They found that people who have more interoceptive awareness (i.e. better heart detection) make better decisions if the anticipatory bodily signals favored advantageous choices. This research result implied that Dunn et al. (2010) assumed that participants who had a high interoceptive awareness were conscious of it, regardless of whether they made right or wrong decisions. Damasio et al. (1996) differ here a bit, they state that when wrong decisions are made that it happens not consciously, thus the feeling results as a bias in the behavior of the participant. There seems to be room for debate on the topic of what the link is between conscious interoceptive awareness and the resulting behavior.

The paper of Mikels, Maglio, Reed, and Kaplowitz (2011) stated that complex decisions usually have a better quality when they are taken in an intuitive way as opposed to a rational way. However, rationalizing the decision after making a decision intuitively lowers the quality of the decision. Despite that this was their main finding, they also found that this finding was not true for intuitive decision making on the domains: physicians, treatments and apartments. To explain this, it was hypothesized that the main finding occurred only in the domains of expertise of the participants.

So to conclude the question: "what role does interoceptive awareness play in intuitive decision making?" The answer is, interoceptive awareness will likely give the person a way to reliably feel his intuition more (i.e. listening to intuition). However, having a higher interoceptive awareness does not mean that the information that intuition gives is a correct (or good) answer to the problem at hand (i.e. having a correct intuition). This is because people who used their intuition either had it more right or more wrong compared to deliberative thinking. On another note, there is too much debate to conclude if interoceptive awareness also aids to the effectiveness of a gut feeling.

4. The neural correlates and brain anatomy of intuition and expertise

To show the neural correlates of intuitive expertise, two papers will be presented with the neural correlates about experts who play Shogi (a Japanese variant of chess). The first paper describes which brain area is active when intuitive best next move generation occurs in a shogi master or shogi amateur. The second paper explains how this intuition is trained by taking two fMRI scans 15 weeks from each other by undergraduates learning Mini Shogi (a simpler variant of Shogi).

The aim of the first study of (Wan et al., 2011, p. 342) was: "revealing neural substrates that underlie quick perception of board pattern and subsequent quick generation of the next best move by measuring the brain activity" of amateur and expert Shogi players. For this, they conducted three experiments. The second and third will be discussed.

In their second experiment they investigated how Shogi players solve checkmate and brinkmate problems. The board patterns were presented in an interval of 1 second and subjects were asked to only report the first move. Then, four response choices were presented and subjects had to select the answer within 2 seconds. After that the subject had to answer some questions about confidence and memory and was engaged to detect a Gold piece (this is a playable piece in Shogi) among serially presented Shogi pieces during the remaining time in each trial. Shogi-pattern presentation was contrasted with the Gold piece detection task. Expert players showed significant activations in: the head of the caudate nucleus, the posterior dorsolateral prefrontal cortex (DLPFC), pre-supplementary motor area, premotor cortex and precuneus. They did not show activation in the caudate nucleus if the Shogi opening patterns only consisted of pieces of the opponent. This means that the caudate head (part of the caudate nucleus) plays a role in generating the best next move intuitively. The magnitude of fMRI signals in the caudate head positively was correlated with the percentage of correct responses ($r = .77, p < .001$). Whereas with the amateur players the caudate head only activated in the first quarter of players who had the shortest response time. There was also a significantly higher precuneus-caudate correlation.

In the third experiment they found that the caudate head activation only happened if the best next move was decided within one second. The finding of the third experiment supports the idea that humans in general have an intuitive way of thinking and a deliberative way.

In a second study Wan et al. (2012) tried to determine whether it was possible to train twenty Japanese undergraduate students – who had little knowledge about Shogi – their intuition within 15 weeks of 40 minutes of practice per day on average in Mini Shogi.

Wan et al. (2012) wanted to see if the undergraduates could attain the ability to quickly generate the best next move. They furthermore wanted to see if the activation of the caudate nucleus would emerge after this training. If this would be the case, then they would have shown what it means to become a Shogi expert at the neural level, since these results were also found in the first study (Wan et al., 2011).

The experimental design was similar to the second experiment of their first study. The most important difference was that they did two fMRI scans, in week 2 or 3 (fMRI 1) and in week 14 or 15 (fMRI 2). They found that multiple cortical areas were activated, such as the DLPFC, dorsal premotor cortex, pre-supplementary motor cortex and posterior precuneus. The magnitude of these cortical activations did not differ on from fMRI 1 to fMRI 2.

This was not the case for activity in the caudate head. It showed a significant increase from fMRI 1 to fMRI 2. Furthermore, as in their first experiment the caudate head activity in participants measured at fMRI 2 was correlated with the percentage of correct responses ($r = .46, p = .02$). They concluded that – based on their first study (Wan et al., 2011) – that the behavioral performance of the undergraduates and caudate head activations at the second fMRI measurement showed a similar dependence on response time compared with high level amateur players who played the traditional variant.

To account for a possible explanation of why the caudate head is involved Wan et al. (2012) provide a possible explanation. This is different from what cognitive scientists have reviewed so far (Björklund, 2007). He reviewed that the caudate nucleus has a static automatic function that helps mediating fast automatic responses (i.e. habits or stimulus-response associations). However, Wan et al. (2012) claim that this is probably not the case.

It is also the case that the brain of an expert is physically different compared to a non-expert. In a study, Grandmaster and Master Chinese Chess players were put into one group and were compared with Chinese novices in the game. These novices knew the rules and basic strategies of Chinese Chess. The study found that Grandmaster and Master Chinese Chess players have a smaller bilateral caudate nucleus and it is more integrated with the default mode network (DMN) of the brain. Specifically it is more significantly connected to the posterior cingulate cortex and the bilateral angular gyrus, compared to novice Chinese Chess players (Duan et al., 2012). This change in the fundamental structure of the DMN is not only the case with expert Chinese Chess players. It is also the case with expert meditators (Brewer et al., 2011; Taylor et al., 2013).

In conclusion, the question was "what are the neural correlates and (relevant) brain anatomy of expert (chess players their) intuitive decisions?" The reviewed literature seems to put the most emphasis on the caudate head (with Shogi players). Furthermore, the research on Chinese Chess players show that the caudate nucleus is more integrated in the DMN. Research on meditation shows that there are also changes in the DMN. In other words, it is likely that developing an intuitive expertise (in shogi) has a visible impact on the brain. Several brain areas change, and they get more connected to the DMN.

Discussion

Conclusion

The main question was "what constitutes effective intuitive decision making?" The problem with this question is that intuition cannot be analyzed into its parts by conventional psychological research methods. Intuition happens as a gut feeling (such as in the recognition-primed-decision model). This means that intuition behaves more as a neural network, and less as an algorithm. As a consequence, only the output of effective intuitive decision making can be studied by psychologists, unless neuroscientific techniques are applied. Hence from the perspective of psychology the question becomes how can one *develop* an effective intuition?

The development of an effective intuition relies on: a high validity environment, a high amount of practice and a high interoceptive awareness. The first two elements account for intuitive answers being right. The third element accounts for the gut feeling being felt by the person. As a result the brain changes, and integrates certain brain areas more into the DMN. The idea that if one has high activation in a brain area a lot, then the structure will be changed there seems to be supported.

Limitations to the conclusion

However, the final statement is not always the case. Wan et al. (2012) reanalyzed the data of expert Shogi players using voxel-based morphometry (VBM). VBM means that gray matter between two groups of subjects is compared per voxel in a local defined brain region (Ashburner & Friston, 2000). A voxel is the 3D space equivalent of what a pixel is in 2D space. Wan et al. (2012) did not find significant anatomical changes in the caudate head of expert Shogi players compared to amateur Shogi players.

Future research

Another question with regards to developing intuition is: should an easier game have been used? In table 1 on page 14 the game tree complexity is stated with a few other games. The tree complexity of a game shows an approximation of how many possible game states there are (i.e. how big the game is).

The table clearly presents that checkers (8 by 8) is a much smaller game than Mini Shogi. This implies that although Mini Shogi is a lot easier to learn than Shogi and chess, an even more easier game could be used in order to investigate effective intuitive decision making in board games. It would be likely that a learning time of 15 weeks has more impact when games are as simple to learn as checkers (8 by 8).

In closing, there is a lot more to discuss on the topic, such as: are there really two systems of thinking, or is that an imposed classification by Kahneman and Klein (2009)? Is there a way to predict how interoceptive awareness works with regards to intuition? Although chess is akin to Shogi, are these results generalizable to each other? Could meditation help in developing more interoceptive awareness (making a person more aware of her intuition)? Questions to which answers still have to be found.

References

Allis, L. V. (1994). Searching for solutions in games and artificial intelligence. Unpublished doctoral dissertation, Rijksuniversiteit Limburg, Maastricht, The Netherlands.

Ashburner, J., & Friston, K. J. (2000). Voxel-based morphometry—the methods. *Neuroimage*, *11*(6), 805–821.

Björklund, L. (2007). The intuitive practitioner: Cognitive aspects on the development of expertise. In *The 13 th international conference on thinking june 17–21, 2007 norrköping, sweden* (p. 25).

Brewer, J. A., Worhunsky, P. D., Gray, J. R., Tang, Y.-Y., Weber, J., & Kober, H. (2011). Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences*, *108*(50), 20254–20259.

Chen, S.-J. Y. J.-C., Yang, T.-N., & Hsu, S.-C. (2004). Computer chinese chess. *ICGA Journal*, *3*, 3–18.

Damasio, A. R., Everitt, B., & Bishop, D. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex [and discussion]. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *351*(1346), 1413–1420.

Dane, E., & Pratt, M. G. (2007). Exploring intuition and its role in managerial decision making. *Academy of Management Review*, *32*(1), 33–54.

Duan, X., Liao, W., Liang, D., Qiu, L., Gao, Q., Liu, C., … Chen, H. (2012). Large-scale brain networks in board game experts: insights from a domain-related task and task-free resting state. *PloS one*, *7*(3), e32532.

Dunn, B. D., Galton, H. C., Morgan, R., Evans, D., Oliver, C., Meyer, M., … Dalgleish, T. (2010). Listening to your heart how interoception shapes emotion experience and intuitive decision making. *Psychological science*, *21*(12), 1835–1844.

Kahneman, D., & Klein, G. (2009). Conditions for intuitive expertise: a failure to disagree. *American Psychologist*, *64*(6), 515.

Krawczyk, D. C., Boggan, A. L., McClelland, M. M., & Bartlett, J. C. (2011). The neural organization of perception in chess experts. *Neuroscience letters*, *499*(2), 64–69.

Mikels, J. A., Maglio, S. J., Reed, A. E., & Kaplowitz, L. J. (2011). Should i go with my gut? investigating the benefits of emotion-focused decision making. *Emotion*, *11*(4), 743.

Ohira, H. (2010). The somatic marker revisited: brain and body in emotional decision making. *Emotion Review*, *2*(3), 245–249.

Samuel, A. L. (1967). Some studies in machine learning using the game of checkers. ii—recent progress. *IBM Journal of research and development*, *11*(6), 601–617.

Schaeffer, J., Burch, N., Björnsson, Y., Kishimoto, A., Müller, M., Lake, R., … Sutphen, S. (2007). Checkers is solved. *science*, *317*(5844), 1518–1522.

Simon, H. A., & Chase, W. G. (1973). Skill in chess. *American scientist*, *61*(4).

Singh, C. (2002). When physical intuition fails. *American Journal of Physics*, *70*(11), 1103–1109.

Taylor, V. A., Daneault, V., Grant, J., Scavone, G., Breton, E., Roffe-Vidal, S., … others (2013). Impact of meditation training on the default mode network during a restful state. *Social cognitive and affective neuroscience*, *8*(1), 4–14.

Wan, X., Nakatani, H., Ueno, K., Asamizuya, T., Cheng, K., & Tanaka, K. (2011). The neural basis of intuitive best next-move generation in board game experts. *Science*, *331*(6015), 341–346.

Wan, X., Takano, D., Asamizuya, T., Suzuki, C., Ueno, K., Cheng, K., … Tanaka, K. (2012). Developing intuition: neural correlates of cognitive-skill learning in caudate nucleus. *The Journal of Neuroscience*, *32*(48), 17492–17501.

Table 1

The calculations are in the formula of $10^{log(bf/ply)}$. *For more information about the branching factor (bf), ply and game tree complexity, see Samuel (1967). Shogi is calculated because Wan et al. (2012) applied different parameters to the game (*$bf = 40$ *and* $ply = 140$*) than other researchers (Chen, Yang, & Hsu, 2004). The game tree complexity of Mini Shogi has never been calculated, but Wan et al. (2012) specified the parameters (*$bf = 20$ *and* $ply = 80$*).*

Game	Tree Complexity (possible moves)	Source
checkers 8 by 8	10^{31}	Schaeffer et al. (2007), they also solved the game, optimal play results in a tie.
Mini Shogi	10^{52}	calculated
checkers 10 by 10	10^{54}	Allis (1994)
chess	10^{123}	Allis (1994)
Shogi	10^{224} or 10^{226}	calculation (10^{224}) and Chen et al. (2004) (10^{226})