Impact of risk on schema-based learning and decision making

Abstract:

Schema is a knowledge organization critical for cognition and decision making via prior knowledge retrieval and new situation interpretation. Such schema-based learning is essential for education, however, the modulatory role of risk on decision making during schema-based learning is rarely known. To evaluate this, painting schema model is adopted. Participants are divided into high risk or low risk group and undergo painting exploration and decision session repetitively to select 4 schemas from the same author in each decision session to earn money. The result proves the existence of learning and validates the effectiveness of the schema-based learning model. It is revealed that the cognition performances are enhanced via the selection shift from low-payoff to high-payoff schemas rather than the improvement of decision accuracy. Also, the risk turns out to have no impact on learning and decision making since no significant differences were found in schema selection and decision accuracy under different risk conditions. The major contribution of this study lies in the establishment of schema-based learning model, enabling the future study of other possible factors. Besides, it also provides us with an intriguing sight into the role of risk on decision making and schema-based learning.

Introduction and literature review:

An enduring belief for cognition is that human actively interact with the environment and constructs their perceptions based on individual experience (Piaget,1973). Schema is an active framework of our past experience. It structures individual's experience and is structured vice versa (Mandler, 1985). To be more specific, schema organizes previous experience in a way where their commonalities are reflected and can retrieved for interpretation of a temporal situation. Meanwhile, schema dynamically adapts itself with the assimilation and accommodation of new evolving experience (Marshall, 2012).

Decision making is associated with schema. Basic cognitive psychology studies suggest that the stocked prior knowledge provided by schema and especially the categorization processes of knowledge benefit decision makers in effective problem solving (Spiegel, 2017). Apart from prior knowledge, risk also influences our decision making. Previous studies indicate that risk-averse behaviors of taking reliable choices with less reward existed in decision making especially under high risk condition (Paulsen etal.,2012). Ventromedial prefrontal cortex(vmPFC)which is critical for decision making is indicated to be involved in new information incorporation by prior schemas, via interacting with hippocampus and prefrontal cortex (Ghosh, 2014; Todd etal., 2009). Though schema-based learning and decision making are well studied, little is known about their interplay and common modulator. In this study, painting schema task is used to detect role of risk on schema-based learning and decision making, establishing the linkage between the two separate fields and providing a model for evaluation of other factors in schema-based learning.

Aim and hypothesis:

Our aim is to investigate performances of schema-based learning and decision making under different risk conditions in painting schema task and we hypothesize that performances of schema-based learning and decision making will be impacted under high risk. It is expected that the payoff earned per decision session to increase overtime to prove existence of learning and validate the effectiveness of the model. Also, we expect that the total comparable earning for

low-risk group is significantly higher than high-risk group, with a higher decision accuracy and schema selection as evidence for promoted learning and decision performances.

Methods and justification:
Participant grouping: Overall 39 undergraduate students in ZJE were involved in the experiment, among which, 15 individuals (4 females, 11 males) participated painting task while the remaining 24 (12 females, 12 males) joined the quote task. Pre-condition data asking self-estimated mental and physiological states and other factors were collected by questionnaire.

Experiment design:
For both task, participants were randomly divided into 4 groups: Lc group, a low-risk group; Hc group, a high-risk group; L group, a low risk group with novelty treatment; H group, a high-risk group with novelty treatment. All groups underwent the exploration and decision session repetitively. In exploration session, participants could freely explore the paintings or quotes from different authors to learn their style, while in the following decision session, participants were guided to choose 4 paintings or quotes from the same authors to earn points. To note, the points for different schemas ranges from 2 to 6 based on difficulty. When participants selected 4 pictures or quotes from the same author, their points earned in current round would be tripled in all groups. Meanwhile, points would only be doubled in the low risk groups, when 3 of 4 chosen paintings or quotes were from the same author. As for groups with novelty treatment, 5 of 10 schemas would be replaced with the new ones at the middle of experiment.

Data process:
The schema experiment data is imported and processed using R (version 3.6.3).
Preprocessing: Equipped with stylistic features, painting data was selected for analysis. As the experiment was self-paced, the time individuals spent on each decision session and the overall rounds for decision varied. The time scale was normalized into range from 0 to 1, in a way where the time length of choosing last schema from a decision session was divided by the total time length. More importantly, both high and low risk groups adopted the payoff calculation method for low risk to make them comparable.

Process: In order to verify existence of schema-based learning in task, the payoff that individuals earned in each decision session was calculated and plotted against normalized time to obtain a general idea for participants' cognition performance changes. Further investigation into the schema selection and decision accuracy were performed to figure out the detailed reason underlie payoff increase. The median schema difficulty chosen in each decision session were collected to represent change of schema selection, while the learning accuracy was checked via decision accuracy distribution. Before use of t-test and ANOVA, Shapiro-Wilk test was used to verify if test data was normally distributed. If qualified, t-test was recruited, to test early phase (dectimes<0.25) and late-phase (dectimes>0.75) data to validate the significance of these changes. As the decision accuracy data is not normally distributed, Mann-Whitney U test was used to test the differences of decision accuracy in the first and the last 10 rounds of decision.

Moreover, we wanted to detect the impact of risk on cognition performances. To avoid influence of novelty, only Lc and Hc data were used. The overall money individuals earned under different risk conditions were compared with t-test, while Mann-Whitney test was used to reveal the

impact of risk on decision accuracy. The influence of risk particularly on high-payoff and low-payoff schema selection was further investigated via one-way ANOVA and Tukey's test.

Result:

Effective learning exists in all groups:

In Fig. 1, the payoff participants earned for each decision phase clearly went up along with time in all groups, the improvement in cognition performances were further validated to be significant for all groups in t-test ($p<0.05$), suggesting the existence of learning. Moreover, novelty introduced at the middle of the experiment seemed to impact participants' cognition performances for a period of time.

Feature of learning: selection for high pay-off schema rather than improvement of accuracy

Additionally, the difference of schema choosing during the early and late phase was detected within ongoing experiment. The linear regressions in Fig. 2 had a clear upward tendency which suggested that gradual shift of individual choices from low-payoff to high-payoff schemas overtime. The following t-test comparing the schema selection in early and late phase confirmed that the shift was important in all groups ($p<0.05$). Compared with the apparent change in schema selection overtime, the decision accuracy remained relatively stable (Fig.3). P value in Mann-Whitney U test for time factor turned out to be larger than 0.05, indicating that there was no significant change in learning accuracy along time.

Risk shows no impact on schema-based learning and decision making:

The risk was proved to have no influence on performance in learning and decision. t-test comparing the total money earned under high and low risk conditions had a p value of $0.1601>0.05$, which suggested the non-effect of risk factor on cognition performances. As shown in Fig.4, the distribution of selected schemas in Lc and Hc groups appeared to similar, thus primarily implied the neutral effect of risk on schema selection. Moreover, one-way ANOVA and Tukey's test revealed that the proportion of choosing high-payoff or low-payoff schemas (Fig.5) was not significantly different under different risk conditions, which further supported the implication ($p>0.05$). From decision accuracy distribution (Fig.3), it was roughly seen that no noticeable differences existed between decision accuracy of high and low risk group. The follow-up Mann-Whitney U test further validated that the neutral effect of risk on decision accuracy ($p>0.05$).

Discussion and Conclusion:

Interpretation of result:

Visualization for payoff changes overtime and its follow-up t-test (Fig. 1) generally indicates that effective learning indeed existed in all groups throughout the task regardless of the manipulation of novelty. This further proves the validity of the painting schema paradigm, suggesting that the model can be used to evaluate effect of other factors related to schema-based learning. Following analysis focused on schema selection and decision accuracy overtime find out that it is the selection shift from low-payoff to high-payoff schemas (Fig. 2) rather than improvement of learning accuracy (Fig. 3) that cause the increase of individual payoff along time (Fig.1). An interesting point is that the slope of Hc payoff curve is suddenly flattened at the late phase of the experiment (Fig. 1). This is supposed to be unrelated with risk factor, since risk functions

throughout the whole procedure and is proved to have no effect on performances in previous tests. Since no extreme cases are detected in the data, it is considered as an effect of small sample size, as there are only 4 participants in Hc group.

Besides, the t-test comparing the overall earning in low and high-risk group clarifies that risk factor appears to have no effect on cognition performance, which is inconsistent with our hypothesis. It is possible that risk indeed has no influence on performances, otherwise it can be resulted by the possibility that the participants in high risk group tend to choose schemas with low payoff to get the bonus, causing high risk and low risk group to obtain similar wages. However, further investigation of schema selection (Fig.4, Fig.5) and one-way ANOVA reveal that both high and low risk group have similar preferences to select high-payoff schemas and there are no significant differences in overall schema selection under different risk conditions. This not only indicates that risk has no impact on schema selection, but also suggests participants in high risk group did not take the risk-averse strategy. Also, the impact of risk on decision accuracy are validated to be neutral via Mann-Whitney U test. In summary, schema selection and decision accuracy are not affected by risk, suggesting non-effect of risk on schema-based learning and decision.

Limitation and future improvement:

A major limitation for this study is the small sample size. Only 15 participants engaged in the painting schema task and were divided into 4 groups, which might cause misinterpretation. For example, the unexpected payoff decreases of Hc group in the later experiment phase could be resulted by this. Such a small sample size largely decreases the statistic power of our result. Thus, it is necessary to take a larger sample size to better represent the population.

Besides, the preconditions collected in this experiment such as stress level, were all estimated subjectively without a standard. So, individuals' rating for the same level may vary largely. To improve this, physiological hormones such as cortisol level can be measured objectively. By doing so, interaction between stress and risk condition can be further investigated. To better eliminate unrelated factors, the experiment group with individuals shift from low-to-high and high-to-low risk can be added. As mentioned earlier, vmPFC region is demonstrated to engage in the schema-based learning, neuroimaging can be applied to reveal possible neuronal circuits involved in the process.

Conclusion:

In conclusion, effective schema-based learning does exist in all groups and risk turned out to have no effect on schema-based learning and decision making. Further improvements in sampling and experiment design are required to increase the statistic power of result.

Figures

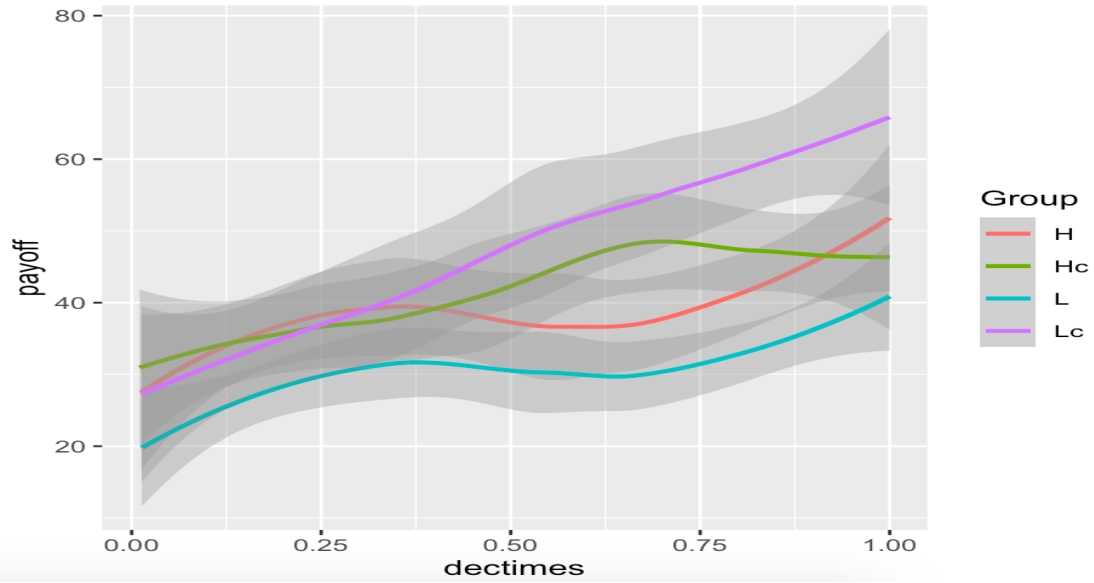

Fig 1. Primary overview of cognition performances changes along time

For all groups, the payoff earned in each decision session increases with time and changes are proved to be significant (Lc: p-value = 5.99e-06, L: p-value=0.002839, Hc: p-value = 0.01193, H: p-value = 0.01568). Novelty seems to have an impact on L and H group.

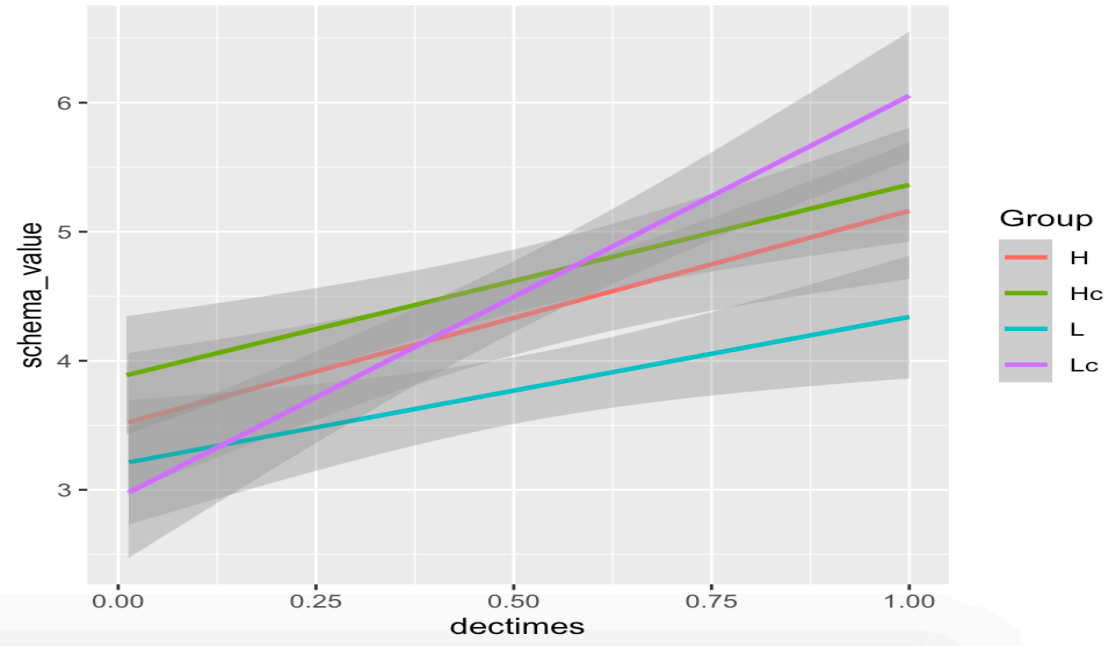

Fig 2. Change of schema selections overtime.

The schema selection gradually shift from low-payoff to high-payoff overtime in all groups. The changes are verified to be significant via t-test comparing the early and late phase data. (Lc: p = 1.836e-06, L: p = 0.01597, Hc: p = 0.004805, H: p = 0.004718)

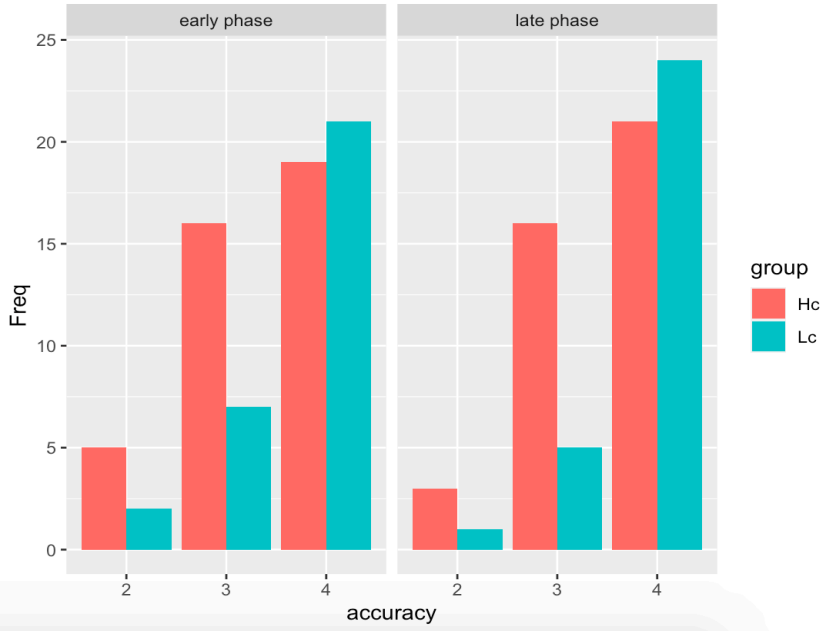

Fig. 3 decision accuracy distribution for early and late phase

The x axis represents accuracy or the number of schemas selected from the same author in a decision session,while the y axis represents the frequency of getting the accuracy. The decision accuracy distribution in the early phase and late phase are validated to be similar (pEarly-Hc:Late-Hc=0.7688, pEarly-Lc:Late-Lc=1) and risk factor is proved to have no effect on decision accuracy (pEarly-Lc:Early-Hc=0.2801, pLate-Lc:Late-Hc=0.3725>0.05).

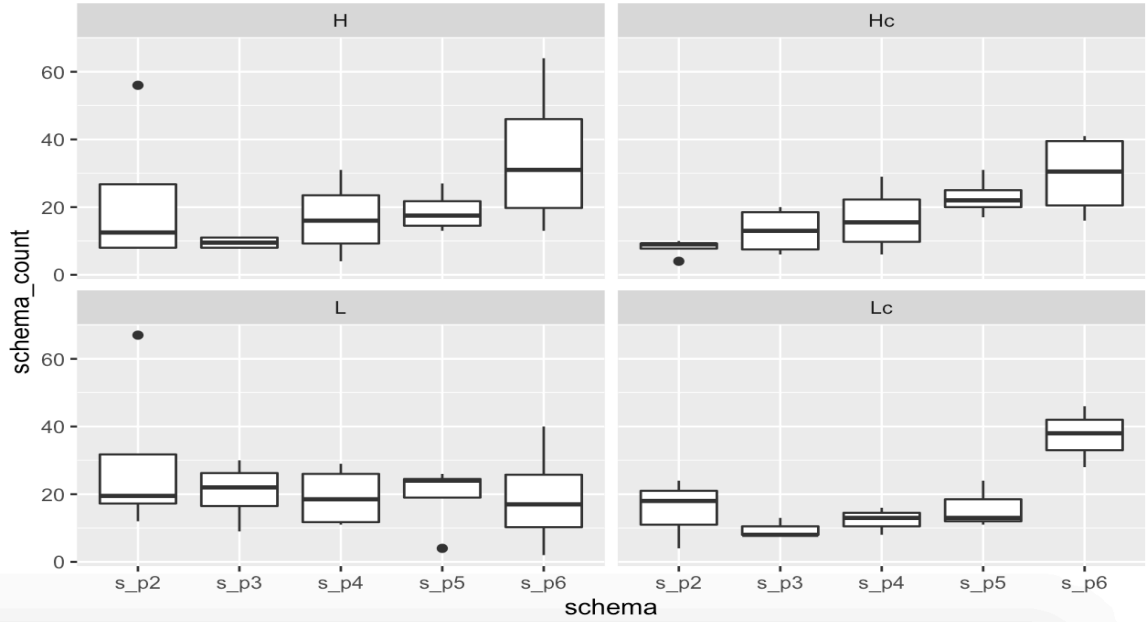

Fig4. Overall schema selection distribution under different risk conditions.

The x axis represents the schemas with different payoff and y axis represents the frequency of choosing the schema. It can be observed that the effect of risk appears to neutral on overall schema selection in Hc and Lc.

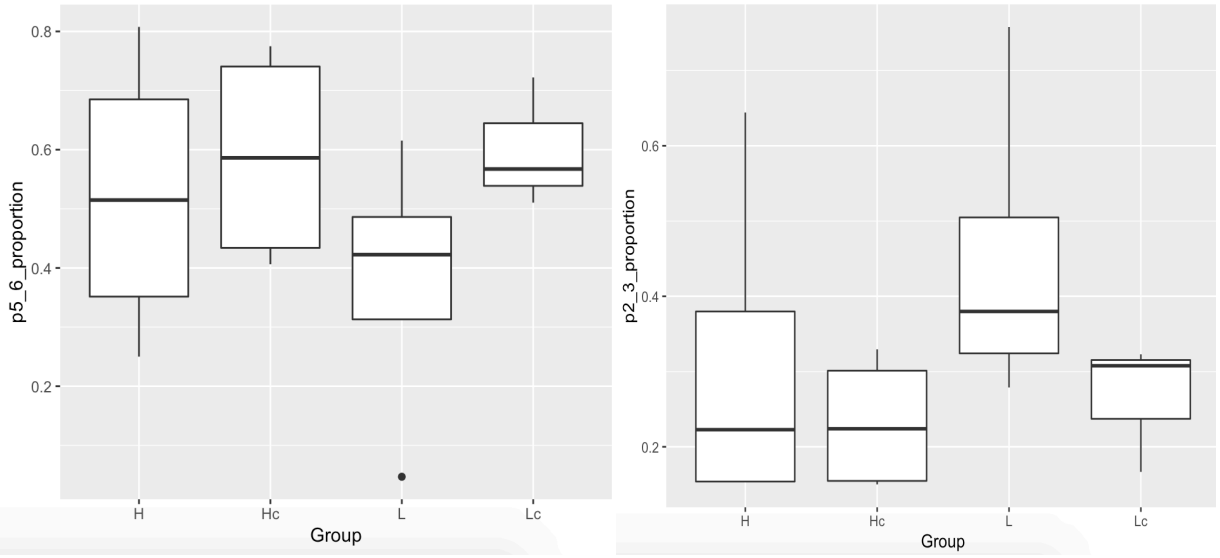

Fig 5. The proportion of selecting high-payoff or low-payoff schema under different risk conditions. All groups showed preferences to select high pay-off schemas. The differences of proportion for selecting high-payoff or low-payoff schemas are validated to be insignificant under different risk conditions via one-way ANOVA. (Lc-Hc high-payoff: p=0.9998595>0.05, Lc-Hc low-payoff: p:0.9939811>0.05).

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