様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

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研究課題名（和文）Cognitive Modeling To Inform the Design of Executive Function Training

研究課題名（英文）Cognitive Modeling To Inform the Design of Executive Function Training

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研究成果の概要（和文）：本研究の目的は、認知モデルを使用して、脳トレゲームで人間の学習メカニズムをどのようにシミュレーションするのか、実現可能性について調査することでした。成功すれば、認知モデルを設計ツールとして使用して、効果的な脳トレゲームの開発に貢献できます。

このアプローチの実現可能性は部分的に実証されましたが、 様々な課題が発見されました。予備的な研究結果については発表され、発見された課題を説明する論文については現在準備中となっています。

研究成果の学術的意義や社会的意義
現代社会では、脳トレゲームと脳トレアプリは手軽にダウンロードし使用できる人気ツールです。一般の方々を始め、認知障害がある方や高齢者の方々も使っています。しかし、それらのゲームとアプリは本当に認知機能を向上させることができるのか、議論がありました。本研究では、脳トレゲームとアプリのデザインを上げるように、認知モデルを開発しました。

研究成果の概要（英文）：The aim of this project was to investigate the feasibility of using computer models of human cognition to simulate how people learn when playing cognitive training games. This involves creating a simplified model of human cognition, which simulates how information is processed during interaction with cognitive training games. This allows us to implement very specific theories of human cognition and compare their performance with results from empirical research involving human subjects. If successful, these models could be used as a design tool, to help us develop more effective cognitive training games.

Overall, while the feasibility of the approach was partially demonstrated, several important challenges were also identified during the research. Preliminary research results have been disseminated at conferences, and a final paper explaining the challenges discovered is currently in preparation.

研究分野：Serious game design

キーワード：Cognitive training　Cognitive models

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

１．研究開始当初の背景

Currently, there is considerable interest, both among the general public and in academic settings, in cognitive training apps and games (sometimes referred to as "brain games"). These artifacts are intended to be entertaining, interactive experiences (e.g., mobile games) which, when played regularly, will improve players' cognitive functions, such as working memory, attention, multitasking, etc. In addition, several companies (e.g., Lumosity) are producing and marketing cognitive training games, and large numbers of customers are paying to access these services. However, research on the effectiveness of cognitive training games is inconclusive. While there are some individual studies which suggest playing such games can improve cognitive function, recent reviews and meta-analyses (e.g., Nguyen et al., 2021) demonstrate only small effects of cognitive training games and similar programs. Thus, further research is necessary; in particular, it is imperative that we understand the potential mechanisms by which cognitive training might be effective (Simones et al., 2016; Smid et al., 2020). Such research would also facilitate the design of more effective cognitive training games; if we can simulate the mechanisms by which engaging with particular tasks (or kinds of tasks) leads to improved general cognitive abilities, it would therefore be straightforward to implement such tasks in cognitive training games that can be used by human players.

２．研究の目的

The aim of this research was to investigate the feasibility of using computational models of cognitive training to understand the mechanisms by which cognitive training might be effective, with a view to improving the design of future cognitive training games. Specifically, this project used an adapted version of the model of task switching presented by Rougier et al. (2005). In their research, the authors showed how the development of abstract representations of cognitive tasks in the prefrontal cortex facilitated improved performance on the tasks and facilitated performance on novel (but similar) tasks through generalization (that is, the abstract representations developed during one task could be used to successfully perform a different, related task). The present research aimed to investigate how variation in the way in which task stimuli are presented (specifically, through the addition of increased noise in the presented stimuli) affected the development of abstract representations. It was postulated that increased noise (e.g., presenting a stimulus within a more complex scene containing random irrelevant stimuli) would facilitate the development of abstract representations better than stimuli presented without such noise.

３．研究の方法

Firstly, the model from Rougier et al. (2005) was implemented in *Emergent* version 8.5.2 using the Leabra learning algorithm. The tasks presented to the model were then adapted into several versions, each incorporating various amounts of additional background noise in the presented stimuli. The model was trained on these tasks, using a subset of the possible stimuli, and then tested on the full set of stimuli. The synaptic weights and connections between layers were examined and compared for the various versions of each task (i.e., comparing how changing the amount of noise affected the synaptic weights and connections between layers), with the aim of identifying units in the prefrontal cortex layer of the model that had learned to represent a specific dimension of the task, such as a color. For example, a subset of units in the prefrontal cortex layer might develop connections to the response layer such that these units are responding to, and representing, the various colors (e.g., red, orange, green, and blue) of a stimulus, which another subset of units in the prefrontal cortex layer will similarly respond to the various shapes (e.g., circle, triangle, square, cross) of a stimulus. As such, the prefrontal cortex layer will have learned to represent the various dimensions of the stimuli (color, shape, etc.) in an abstract, generalized way.

４．研究成果

It was possible to implement the model from Rougier et al. (2005) and replicate their findings. The tasks were then altered to add various levels of additional noise in the presented stimuli.

Subsequent training of the model on these altered tasks demonstrated mixed results. Firstly, while it was possible to identify the formation of abstract representations for some of the altered tasks but not others, it was difficult to identify how the variation in noise was affecting whether abstract representations developed, and to quantify the level of abstract representation (i.e., to compare two versions which developed abstract representations). Secondly, it was difficult to interpret the results without comparable empirical data from human subjects training on the same tasks. Since a cognitive model is a computational implementation of a theory of cognition, it is necessary to obtain human data to fully test the theory. However, the original research plan did not involve the collection of human data, so such comparisons were impossible. An additional challenge to this approach was identified, in that determining how to introduce noise into the stimuli in a way that would be feasible in a real cognitive training game for human use was difficult. Again, empirical data from human subjects would help to mitigate this issue. Overall, the main findings of this research are that it is feasible to implement computational models of cognitive training games and to alter the tasks presented to these models to test theories about the mechanisms by which cognitive training might be effective (e.g., the formation of abstract representations). However, challenges to this approach remain, and future research should incorporate empirical data from human subjects to fully understand and interpret results.

References

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Smid, C. R., Karbach, J., & Steinbeis, N. (2020). Toward a science of effective cognitive training. Current Directions in Psychological Science, 29(6), 531-537.

5．主な発表論文等

〔雑誌論文〕　計1件（うち査読付論文　1件／うち国際共著　0件／うちオープンアクセス　1件）

1．著者名 Nigel ROBB	4．巻 10
2．論文標題 Attitudes and habits regarding brain training applications and games among Japanese consumers: a cross-sectional study	5．発行年 2021年
3．雑誌名 F1000 Research	6．最初と最後の頁 1 - 14
掲載論文のDOI（デジタルオブジェクト識別子） 10.12688/f1000research.42125.1	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 －

〔学会発表〕　計2件（うち招待講演　0件／うち国際学会　1件）

1．発表者名 Nigel Robb
2．発表標題 Modeling task representations in the prefrontal cortex during skill acquisition
3．学会等名 University of Tokyo Faculty Research Forum
4．発表年 2020年

1．発表者名 Nigel Robb
2．発表標題 Towards Better Brain Training: A Computational Cognitive Modelling Approach to Improving the Design ofExecutive Function Training in Educational Contexts
3．学会等名 The Asian Conference on Education（国際学会）
4．発表年 2019年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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6．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関