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論文題目	Expansion of Game Refinement Theory into Continuous Movement Games with Consideration on Functional Brain Measurement （ゲーム洗練度の理論の連続的ゲームへの拡張とゲームプレーヤの機能性脳活動測定）			
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論文の内容の要旨

Game theory has expanded far and beyond its original contexts into all manner of subjects. There are still many unsettled questions at both ends of the spectrum of applied, normative uses, and theoretical, descriptive inquiry. A wide range of scientific inquiry explores the domain of games for various purposes from that of pure play to serious business, and all of the many combinations thereof. Among these, game refinement theory is a child of the computer chess problem, and a close relative of artificial intelligence for games.　Survey work of game theory, game refinement theory, the game progress model, and functional brain imaging for gamers during gaming is briefly undertaken throughout the relevant sections. The introductory chapter presents considerations on the study of recreational games and strategic interplay, and some of the problems facing game refinement theory. Namely, there is a lack of experimentation to test the theory that information accelerates in the mind of players and observers as the game progresses.

In Chapter 2, game theory as the game player's paradigm is discussed. Some of the tools which have been adopted for use in the study of recreational gaming are examined, and game refinement theory is explained in the framework of its theoretical relatives.

In Chapter 3, game refinement theory as the game maker's paradigm is discussed. Past studies of the state of AI for board games are mentioned and updated. The game

refinement model and prior works are broken down, and game refinement values for various games and game types are compared. Also, recent work in the search for reasonable quantities to relate the model of discrete board game measures to that of continuous movement games is presented. The results of sub-studies and experiments relating discrete elements of non-discrete games in the board game format are considered. A bridging principle is now sought for guidance to help prove the acceleration of information in the brain during games. Game information dynamic theory makes a bold claim that information ow is governed by physical laws of motion. Without denying or supporting this claim, it is explored briefly with consideration on the principle bridging information and hydrodynamics.

Preliminary work in functional brain measurement of gamers during gaming is presented in Chapter 4 with potential for becoming a useful component of verification for game refinement theory. The intersection of fNIRS brain measurement and games is an expanding field with excellent potential for game scientists. Prior studies have been carried out within the established protocols and frameworks of cognitive neuroscience. The well-developed model of games as a vehicle of experimentation for neuroscientists is being established, and games are recommended for those engaged in brain studies, as with brain activity measurement for those in the research of AI and games.

Lastly, results and implications from observations in continuous movement games are discussed along with the fitness of the model. Rule changes in most of the observed games show game refinement values for continuous movement games gravitating towards that seen in early work in board games. Theorists have been careful not to venture why the phenomenon of a game refinement window appears, noting a dearth of knowledge of the physics of information in the mind. Game information dynamics proposes that information might have measurable physical properties. Considering both these thoughts, the next experiments using functional brain imaging are outlined with the intention of capturing evidence of game information accelerating at game's end in the brains of gamers.

Keywords: *game theory, game refinement theory, sports, brain imaging, fNIRS*

論文審査の結果の要旨

本博士論文は，ゲーム洗練度の理論を広い分野のゲームに拡張すると同時に，ゲーム中に感じる情報加速度に関して脳活動計測の観点から考察を加えたものである。従来のゲーム理論について例を示しながら説明し，本論文で扱ったゲーム洗練度の詳細を説明した。次に，本研究の主眼と言える，他分野（思考ゲーム以外のゲーム）への応用について，主たる研究成果を説明した。チェスや将棋のような離散時間型の思考ゲームだけでなく，連続時間型のスポーツゲームにおいても，ゲーム洗練度を応用できることについて示した。また，「わかったモーメント」という概念と関連して，ゲーム中のプレイヤの脳活動計測についての研究成果と幅広いサーベイを示した。ゲームプレイヤの脳活動については，必ずしも顕著な業績となってはいないが，今後の展望を明らかにすることで，当該分野に貢献できた。最後に，本研究の重要課題とそれに対する答えをまとめた。

当該候補者は，博士論文研究の内容を約５０分間，スライドを用いながらプレゼンした。プレゼンは英語で実施され，当人自身の貢献を他者の業績と区別し，それぞれのポイントを押さえつつ，非常に明確であった。プレゼンの後，審査員の先生方から，種々の観点に基づいて質疑がなされた。新規性，関連研究，アプローチの妥当性，応用や今後の展望など，多岐にわたり質疑が行われた。それぞれの質問に対する候補者の答えは満足できるものであり，候補者の研究能力の確かさを示している。

以上のプレゼンおよび質疑は公聴会として一般公開の形で実施されたが，その後，候補者と審査員だけで能力試験が実施された。候補者の人物，資質，これまでの勉学，基礎学力，今後のことなどが言及された。ここにおいても質疑は十分に的を得たものであり，全般にわたって，候補者の優れた能力を示すものである。

以上，本論文は，ゲーム洗練度の理論についてさらなる発展を実現したものであり，学術的に貢献するところが大きい。よって博士（情報科学）の学位論文として十分価値あるものと認めた。