Understanding How Players Solve Puzzles

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Abstract

Pen-and-paper puzzles offer a controlled environment to study problem-solving, player behaviour, and engagement. This abstract describes how players interact with unfamiliar puzzles, building upon existing research in the puzzle solving, explanation and hint-systems. We investigated how hints help players in explaining and/or indicating next steps in solving puzzles for a particular puzzle (Binairo). The analysis found that players using hints generally performed better, completed more puzzles, and showed signs of strategic thinking. This suggests that the availability of hints may have implications for playability, engagement and facilitating mental focus.

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1 Introduction

"Progressive pen and paper puzzles (PPPP)" are puzzles designed to be solved on paper, using a pen – they commonly appear in newspaper pages, magazines and specialist books. Popular PPPPs include Sudoku, Futoshiki and Skyscrapers, but new puzzles and variants are created almost weekly, and there are many websites and books dedicated to showing off new problems.

One example of a PPPP is *Binairo* (see an example in Figure 1) which is a grid-based logic puzzle, but instead of numbers, players fill an $n \times n$ grid with 0 or 1 (black/white, 0/X) while following three constraints: **1.** Each cell must be either black or white, **2.** No more than two identical cells may appear consecutively in any row or column. **3.** No two rows or columns can be identical.

Based on Lynch (2024) [4] where the efficacy of current hint systems is discussed and proposes a new methodology which, instead of being given the answer, players are directed to focus on a particular area of play rather than being given explicit answers.

While Lynch's work primarily evaluated types of hints (in Binairo puzzles amongst others), this work shifts focus toward player behaviour and the impact of hints rather than their implementation. Using the dataset she collected, which includes hundreds of completed Binairo games, the aim is to uncover behavioural trends and deeper insights into puzzle

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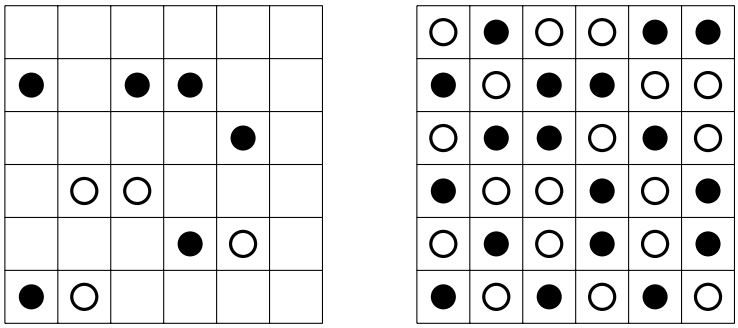

Figure 1 Incomplete Binairo and its solution

difficulty and engagement. This work seeks to provide a contextual analysis of how players interact with puzzles in varying conditions, and aims to find correlations and recurring themes in player behaviour. This work is a stepping stone towards reliably guiding tools which generate explanations towards "user-friendly" or useful explanations. It could aid papers such as [3, 1, 2] with a theory as to why their generated explanations are "good".

We identified the following points of interest from our further analysis of the results:

- Player accuracy improved and error rates declined the more puzzles a player completed, suggesting both learning and increased engagement over time.
- Players who used hints tended to perform better across key metrics. They were more accurate and had higher completion rates. Interestingly, they also took longer to solve puzzles, indicating that the played the game more carefully.
- In addition to performance improvements, players who used hints tended to engage with the puzzles more effectively and for longer. This suggests the hint system not only aided with the puzzles themselves but also increased engagement.

These findings were corroborated by analysing quitting behaviour and continuation rates, which highlighted the importance of experience and timing in determining player retention, especially when it came in response to difficulty spikes.

This analysis points toward several use cases:

1. Do certain puzzle type hints/explanations convince players to play for longer? **2.** Do players feel more in control if the hint is less explicit and the explanation still gives them agency? **3.** Can intuitive explanations be reliably generated by algorithms?

Future work will involve mixed methods to investigate the psychology behind generated explanations/hints and engagement.

References

1 J E Arxer, I P Gent, R Hoffmann, C Jefferson, M J McIlree, and A M Lynch. Towards generic explanations for pen and paper puzzles with muses. In *SICSA eXplainable Artifical Intelligence Workshop*, 2021.

2 I Bleukx, J Devriendt, E Gamba, B Bogaerts, and T Guns. Simplifying Step-Wise Explanation Sequences. In *29th International Conference on Principles and Practice of Constraint Programming*, 2023.

3 E Gamba, B Bogaerts, and T Guns. Efficiently explaining csps with unsatisfiable subset optimization. *Journal of Artificial Intelligence Research*, 2023.

4 A M Lynch. *Effective player guidance in logic puzzles.* PhD thesis, The University of St Andrews, 2024.