THE SCIENTIFICATION OF GAMES: ANALYZING *GHOST BLITZ* THROUGH THE LENS OF COGNITIVE PSYCHOLOGY

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Abstract

This article provides a proof-of-concept for the complementary route of the *scientification of games*. We argue that the tasks and rules developed within commercially available games can exactly represent the same kinds of tasks studied in Cognitive Psychology. Consequently, analyzing games as though they were scientific paradigms a) allows for unique teachable moments in Cognitive Psychology using games as the vehicle of delivery, and b) feeds back principles of randomization and counterbalancing into the design and development of commercial games. Using the popular card game *Ghost Blitz*, we identify how players might resolve the game on a round-by-round basis in terms of both bottom-up (stimulus-driven) and top-down (expectation-driven) processes. We identify statistical biases within the card deck favoring one rule over the other, and a second bias where specific color/shape conjunctions are both under- and over-represented. These detailed analyses provided the insights necessary to present a re-designed and balanced version of the game and allow for teachable moments with respect to Cognitive Psychology including feature versus conjunction processing, visual search asymmetries, and task switching.

Keywords

card games, *Ghost Blitz*, cognitive psychology, player psychology, game statistics, scientification

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A strong case has recently been made for the *gamification* of behavioral science.[1] The proposal is that aspects of game design can be implemented into the design and distribution of scientific paradigms, thereby overcoming some of the traditional pitfalls associated with laboratory-based data collection. For example, gamified science may help to increase the diversity of populations from whom data are collected, improve statistical power by exceeding traditional sample sizes, and,

[1] B. Long, J. Simson, A. Buxo-Lugo, D. G. Watson and S. A. Mehr, "How Games Can Make Behavioural Science Better," *Nature* 613 (2023), 433-436.

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Figure 1: An example of a Rule A card where one of the objects on the card represents a shape in the same color as the physical object. Here, the grey mouse (yM) should be selected as fast as possible. Photo by authors.

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enable reproducibility by making the code or rules associated with game implementation freely available.[2] We identify the complementary route of the *scientification* of games, revealing what popular games like judi slot can teach us about behavioral science. Games represent simulations of environments both concrete and abstract, real and imaginary, where players take on novel roles of agency and adopt shared rule sets to maximize outcomes via optimized decision-making.[3] In these respects, the tasks and rules developed within games often exactly represent the same kinds of tasks studied in behavioral science, and—specifically in our field of interest—Cognitive Psychology. For example, analog games such as Chess, Go, *Scrabble* and Shogi[4] are leveraged to explore the

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[2] Long et al., "How Games Can."
[3] J. Huizinga, *Homo Ludens: A Study of the Play-Element of Culture* (London: Routledge & Kegan Paul, 1949) and C. T. Nguyen, Games: *Agency as Art* (Oxford University Press, 2020).
[4] See F. Gobet and G. Clarkson, Chunks in Expert Memory: Evidence for the Magical Number Four…or Is It Two?," *Memory* 12, No. 6 (2004), 732-747; D. F. Halpern and J. Wai, "The World of Competitive *Scrabble*: Novice and Expert Differences in Visuospatial and Verbal Abilities," *Journal of Experimental Psychology: Applied*

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development and expression of domain expertise. Similarly, the card game *SET*,[5] advertised as "the family game of visual perception," has been studied as a paradigm through which the interaction between perceptual and conceptual information may be understood.[6] To further demonstrate the value of exploring the scientific content of commercially developed games, we will perform an analysis of the card game *Ghost Blitz*.[7]

Ghost Blitz is a card game for 2 to 8 players involving 5 physical objects and a deck of 60 cards. The physical objects represent 5 unique conjunctions of a color and a shape: a red chair (rC), a blue book (bB), a grey mouse (yM), a green bottle (gT), and, a white ghost (wG).[8] Each round of the game consists of a card played face-up to all players, with the card depicting two of the physical objects in specific colors. The specific objects on the card determine one of two correct actions for the round. First, if one of the objects on the card represents a shape in the same color as the physical object, players must take (or, more accurately, grab) that physical object (*Rule A*). For example, a card (bGyM) depicting a blue ghost (bG) with a grey mouse (yM) requires taking the grey mouse from the table (see Figure 1 above).

Second, if both objects on the card represent shapes in colors *different* to those of the physical objects, players must take the only remaining physical object represented by none of the shapes nor colors on the card (*Rule B*). For example, a card (rMwT) depicting a red mouse (rM) with a white bottle (wT) requires taking the blue book (bB) from the table (see Figure 2). To elaborate on this justification, white (w) eliminates the white ghost (wG), bottle (T) eliminates the green bottle (gT), red (r) eliminates the red chair (rC), and mouse (M) eliminates the grey mouse (yM): hence the only object not represented on the card is the blue book (bB). The fastest player to perform the correct action will win that round (and keep the card). A player that performs an incorrect action must lose a card they have already won. The winner of the game is the player with the most cards after all 60 cards have been revealed.

The first impact of this *scientification of games* approach is that allows for unique teachable moments in Cognitive Psychology using games as the vehicle of delivery. Specifically, *Ghost Blitz* offers insights into featural versus conjunctive processing,[9] visual search asymmetries,[10] and task switching.[11] In terms of featural versus conjunctive processing, each card presents its players with 4 visual features (2 colors and 2 shapes). However, featural information in and of itself does not resolve the object that must be selected. For example, knowing that there are both blue and white colors, and both mouse and book shapes on the card does not help to initiate *Rule A* or *Rule B*.

13, No. 2 (2007), 79-94; H. Nakatani and Y. Yamaguchi, "Quick Concurrent Responses to Global and Local Cognitive Information Underlie Intuitive Understanding in Board-Game Experts," *Scientific Reports*, 4 (2014), 5894; and X. Wan, H. Nakatani, K. Ueno, T. Asamizuya, K. Cheng, and K. Tanaka, "The Neural Basis of Intuitive Best Next-Move Generation in Board Game Experts," *Science* 331, No. 6015 (2011), 341-346.

[5] M. J. Falco, *Set: The Family Game of Visual Perception* [Board game] (Set Enterprises, 1998).

[6] M. Jacob & S. Hochstein, "Set Recognition as a Window to Perceptual and Cognitive Processes," *Perception & Psychophysics* 70 (2008), 1165-1184 and E. Nyamsuren and N. A. Taatgen, "Set as an Instance of a Real-World Visual-Cognitive Task," *Cognitive Science* 37 (2013), 146-175.

[7] J. Zeimet, *Ghost Blitz* [Board game] (Zoch Verlag, 2010).

[8] Objects are defined by a primary lower-case letter for color ([r]ed, [b]lue, gre[y], [g]reen, [w]hite) and a secondary upper case for shape ([C]hair, [B]ook, [M]ouse, bo[T]tle, [G]host).

[9] A. Treisman, "The Binding Problem," *Current Opinions in Neurobiology* 6 (1999), 171- 178.

[10] J. Wolfe, "Asymmetries in Visual Search: An Introduction," *Perception & Psychophysics* 63 (2001), 381-389.

[11] A. Kiesel, M. Steinhauser M. Wendt, M Falkenstein, K. Jost, A. M. Philipp and I. Koch, "Control and Interference in Task Switching—a Review," *Psychological Bulletin* 136 (2010), 849-74.

Figure 2: An example of a Rule B card where both objects on the card represent shapes in colors different to those of the physical objects. In these cases, players must take the only remaining physical object represented by none of the shapes nor colors on the card. Here, the blue book (bB) should be selected as fast as possible.

Rather, the specific conjunctions of featural information guide the play towards the correct action: if blue is conjoined to book (bB) then this initiates *Rule A* but if blue is conjoined to mouse (bM) then this does not initiate *Rule A*. This observation further highlights the presence of visual search asymmetries within the game. Here, the *presence* of an object on the card that matches a physical object on the table should successfully initiate *Rule A*. In contrast, the *absenc*e of an object on the card that matches a physical object on the table should successfully initiate *RuleB*. From scientific studies comparing performance when visual search is defined by the presence and absence of features, *Rule A* should be completed faster and more accurately relative to *Rule B*. Finally, the use of two rules in *Ghost Blitz* raises the possibility of observing task switching costs in the game. Previous data show that being able to re-use the same set of cognitive processes across separate events leads to efficiency (*task repetition*), relative to when different cognitive processes are required (*task switching*). From the above analysis, the rule (or task) required at each round of *Ghost Blitz* is determined by the specific nature of the information presented on the card. In this respect, the game has a strong ‘stimulus-driven’ (or bottom-up) component, where rule information must be quickly resolved, but only once the card is revealed. This is consistent with marketing for the game as “a lightning fast shape and color recognition game.”[12] However, we also ask whether there were hidden statistical biases within *Ghost Blitz* that enabled ‘expectation-driven’ (or top-down) contributions to the game. Specifically, we asked whether there were a) differences in the frequency of *Rule A* and *Rule B* enabling players to anticipate one rule over another, and, b) differences in the distribution of color and shapes that might also allow players to anticipate certain objects over others. From the Cognitive Psychology literature, participants can leverage the increased likelihood of more frequently presented stimuli and tasks to make processing more efficient.[13]

Of the 60 cards used in *Ghost Blitz*, Table 1 identifies 20 cards that require the initiation of *Rule A* (physical object present on card) and 40 cards that require the initiation of *Rule B* (physical object absent on card). Therefore, we conclude there is a hidden statistical bias in *Ghost Blitz* with respect to the unequal distribution of the two rules of the game, with *Rule B* appearing twice as frequently as *Rule A*. As such, players could maximize performance by, on average, preparing to identify the features that are *absent* on the card (*Rule B*) rather than the features that are present (*Rule A*).

Table 1 also contains a summary of our featural analysis of the number of times the 5 colors and 5 shapes appear on the deck of 60 cards, further divided by Rule A and Rule B (Supplementary Table A provides a card-by-card breakdown). The rationale here was similar to that of our rule analysis: if certain visual features appeared more or less often than others then this would represent a second form of statistical bias that could be leveraged by players. For cards representing *Rule B*, all colors and all shapes were equally represented. For cards representing *Rule* A, all shapes were equally represented but there was a slight underrepresentation of blue and grey (one fewer) and a slight overrepresentation of red and white (one more). This analysis inspired us to perform an even more detailed examination of the cards with respect to the frequency of specific objects (e.g., *white ghost* rather than *white* and *ghost*; see Table 2; Supplementary Table B provides a card-by-card breakdown). Here, we observed a number of imbalances in the distribution of specific objects. However, our analysis of Table 2 provides us with the structure to resolve these discrepancies and propose a revised version of *Ghost Blitz* wherein all combinations of color and shape appear equally within each deck, as far as the rules of the game will allow. Two observations are key. First, with respect to *Rule B* (where cards cannot contain objects of color and shape combinations represented by physical objects), our analysis of the original *Ghost Blitz* cards containing *white* colors (wC, wB, wM, wT, wG; right-most column in Table 2) produces an equal distribution of *white* objects that are not *ghosts*. Therefore, when reconsidering *Rule B* cards, there must be 4 presentations of the 4 shapes that are not the physical shape for that color (e.g., *green chair, green book, green mouse, green ghost*, but not *green bottle*). Second, with respect to *Rule A*, there is a clear balancing of the frequency of the five objects that must appear to initiate *Rule A* (*red chair, blue book, grey mouse, green bottle, white ghost*), with each critical object appearing 4 times (5 objects x 4 presentations = 20 cards). Since there are 20 remaining conjunctions of color and shape that do not represent any of

[12] Zeimet, *Ghost Blitz*.
[13] See D. Kerzel, C. Balbiani, S. Rosa and S. H. Cong, “Statistical Learning in Visual Search Reflects Distractor Rarity Not Only Attentional Suppression,” *Psychonomic Bulletin & Review* 29 (2022), 1890-1897; V. Maljkovic and K. Nakayama, “Priming of Pop-Out: I. Role of Features,” *Memory & Cognition* 22 (1994), 657–672; and D. Nessler, D. Friedman and R. Johnson, Jr., “A New Account of the Effect of Probability on Task Switching: ERP Evidence Following the Manipulation of Switch Probability, Cue Informativeness, and Predictability,” *Biological Psychology* 91 (2012), 245-262.

the physical objects, it follows that each of these objects should appear on only 1 of these 20 Rule A cards (see Rule A blue color analysis in Table 2 for an approximation of this scheme).

Table 1: Feature Distribution Summaries for Colors and Shapes in Original and Revised Versions of *Ghost Blitz*

	Color					**Shape**				
Feature	Red	Blue	Grey	Green	White	Chair	Book	Mouse	Bottle	Ghost
Original 60 set										
Rule A (n=20)	9	7	7	8	9	8	8	8	8	8
Rule B (n=40)	16	16	16	16	16	16	16	16	16	16
Total	**25**	**23**	**23**	**24**	**25**	**24**	**24**	**24**	**24**	**24**
Revised 60 sets										
Rule A (n=20)	8	8	8	8	8	8	8	8	8	8
Rule B (n=40)	16	16	16	16	16	16	16	16	16	16
Total	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**
Revised 120 set										
Rule A (n=60)	24	24	24	24	24	24	24	24	24	24
Rule B (n=60)	24	24	24	24	24	24	24	24	24	24
Total	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**

The second impact of this *scientification of games* approach is that by considering principles of randomization and counterbalancing in the design of commercial games, new variants reveal themselves. We first offer a revised set of 60 cards for *Ghost Blitz* that resolves the imbalance of visual features in the original set (see Tables 1 and 2; also Supplementary Tables C and D for card-by-card breakdowns). With respect to featural distribution (see Table 1), we have corrected the underrepresentation of blue and grey, and the overrepresentation of red and white, such that all 5 colors now appear 24 times across the card set (8 times in *Rule A* cards, 16 times in *Rule B* cards). This is at the same time as maintaining the equal distribution of shapes that was apparent in the original version of the game. With respect to object distribution (see Table 2), this same revised set of 60 cards also produces an equivalency in terms of the specific pairing of objects across the deck. For Set A cards, and for any given matched object that must appear on the card (e.g., red chair; rC), every other colour (eg, blue, white, green, grey) and every other shape (eg, ghost, bottle, mouse, book) appears only once (hence, the set rCbG, rCwT, rCgM, rCyB; see Supplementary Table D). For Set B cards, the same constraint is also true: for any given object that represents a non-Rule A conjunction of color and shape (e.g., red book; rB), every other color (eg, blue, grey, green, white) and every other shape (e.g., mouse, bottle, ghost, chair) appears only once (hence, the set rBbM, rByT, rBgG, rBwC; again see Supplementary Table D). An accidental byproduct of this first re-design was that half of the *Rule B* cards had two rather than one solution.[14] For example, *Rule B* card bCyB represents the presentation of a blue chair with grey book: the chair eliminates red, grey eliminates the mouse, blue eliminates the book *but so too the book eliminates blue*. Therefore, either the white ghost or the green bottle would be viable correct responses to this card. Such cards

[14] We thank Eunchan Na and Yajing Zhang for pointing this out.

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could offer a more ‘relaxed’ style of gameplay where the constraints associated with correct responding are more liberal.[15] This could be an attractive game element for younger players who may struggle with the logic of card-object interactions for *Rule B*. A second, revised 60 card set (see Tables 1 and 2; see also Supplementary Tables E and F for card-by-card breakdowns) removes the presence of two-solution Rule B cards by introducing two duplicate cards (rTbM and wTyB). A third 120 card set (see Supplementary Tables G and H for card-by-card breakdowns) expands the Ghost Blitz universe by offering all features and conjunctions equally across the deck (as far individual rules can allow), while also equating for the appearance of *Rule A* and *Rule B* and removing the rouge presence of a singular, duplicate card.

Table 2: Object Distribution Summaries for Color and Shape in Original and Revised Versions of *Ghost Blitz*

Object	rC^	rB	rM	rT	rG	bC	bB^	bM	bT	bG	yC	yB	yM^	yT	yG	gC	gB	gM	gT^	gG	wC	wB	wM	wT	wG^
Original 60 set																									
Rule A	4^	2	2	0	1	1	4^	1	0	1	0	0	4^	1	2	2	2	0	4^	0	1	0	1	3	4^
Rule B	0	5	4	3	4	4	0	3	5	4	5	2	0	4	5	3	5	5	0	3	4	4	4	4	0
Total	**4^**	**7**	**6**	**3**	**5**	**5**	**4^**	**4**	**5**	**5**	**5**	**2**	**4^**	**5**	**7**	**5**	**7**	**5**	**4^**	**3**	**5**	**4**	**5**	**7**	**4^**
Revised 60 sets																									
Rule A	4^	1	1	1	1	1	4^	1	1	1	1	1	4^	1	1	1	1	1	4^	1	1	1	1	1	4^
Rule B	0	4	4	4	4	4	0	4	4	4	4	4	0	4	4	4	4	4	0	4	4	4	4	4	0
Total	**4^**	**5**	**5**	**5**	**5**	**5**	**4^**	**5**	**5**	**5**	**5**	**5**	**4^**	**5**	**5**	**5**	**5**	**5**	**4^**	**5**	**5**	**5**	**5**	**5**	**4^**
Revised 120 set																									
Rule A	12^	3	3	3	3	3	12^	3	3	3	3	3	12^	3	3	3	3	3	12^	3	3	3	3	3	12^
Rule B	0	6	6	6	6	6	0	6	6	6	6	6	0	6	6	6	6	6	0	6	6	6	6	6	0
Total	**12^**	**9**	**9**	**9**	**9**	**9**	**12^**	**9**	**9**	**9**	**9**	**9**	**12^**	**9**	**9**	**9**	**9**	**9**	**12^**	**9**	**9**	**9**	**9**	**9**	**12^**

Note: r = Red, b = Blue, y = Grey, g = Green, w = White, C = Chair, B = Book, M = Mouse, T = Bottle, G = Ghost,
^ denotes object conjunction that should initiate Rule A

In applying the empirical method to commercially available games, we identify unique teachable moments related to scientific principles, and, offer new game variants by considering how the game has been randomized or counterbalanced. In particular, we identified how players might resolve the game on a round-by-round basis in terms of both bottom-up (stimulus-driven) and top-down (expectation-driven) processes.[16] We identified both a statistical bias within the card deck favoring one rule over the other (*Rule A* cards < *Rule B* cards), and, a second bias where specific color/shape pairings were both under- and over-represented. These detailed analyses provided the insight necessary to resolve the second bias and present balanced versions of *Ghost Blitz* where all combinations of color and shapes appear equally within the deck, as far as each of the two rules of the game will allow.

It remains an open question however as to whether the variants emerging from our analysis would actually lead to better games. In the case of having both *Rule A* and *Rule B* appear with equal

[15] This led us to consider a third type of *Rule B* card where two physical objects are completely crossed with respect to the features presented on the case, e.g., gCrT: green chair with red bottle. This would mean that any of the remaining *three* physical objects (blue book, grey mouse, white ghost) could be correct.
[16] Nyamsuren and Taatgen, “Set as an Instance.”

frequency, this removes a potential moment of insight (an "aha" moment[17]) that emerging *Ghost Blitz* experts could have in that one rule appears more often than another. Competing against opponents who were not privy to this information would provide a natural advantage to playing, in that the cognitive processing required by the game could be maximized by preparing for the most likely outcome. Again, the marketing of the game as "a lightning fast shape and color recognition game" would seem to place the emphasis on *Ghost Blitz*'s demand for perceptual decision-making and action under extreme time pressures (i.e., bottom-up) rather than a more measured consideration of statistical imbalances in card deck (i.e., top-down). Such "card-counting" approaches[18] may be implicitly encouraged by the inclusion of a distribution list as part of the rules (cf., the card distribution list in *Brass: Birmingham*,[19] or tile distribution list in *Kingdomino*[20]). Given the speed of the game, it seems unlikely that players could be able to card count in *Ghost Blitz*, apart from leveraging the initial bias towards *Rule B* cards.

We are also able to pinpoint a number of other exciting scientific principles applicable to *Ghost Blitz*. First, we reflect on the specific combinations of color and shape selected for the physical objects. The principle of *correspondences* strongly argues for natural pairs of basic perceptual features both within and across modalities. For example, examined the ease with which combinations of colors and abstract shapes were seen to match.[21] Correspondences may also occur at a *statistical* level[22] where the ease of coupling between features is reflected in environmental regularities. In the context of *Ghost Blitz*, we argue that *white ghost*, *green bottle* and *grey mouse* all intuitively represent if not environmental regularities, then stereotyped regularities and thereby, statistical correspondences. Game performance could be impacted by the efficiency with which certain *objects* are processed. For example, *Rule A* cards where the required object represents an example of statistical correspondence may be actioned faster than *Rule A* cards featuring required objects that do not represent such correspondences (*red chair*, *blue book*).[23] We will formally test these, and other empirical hypotheses related to search asymmetries and task switching, in future experiments.

The fascinating complexities that emerge from a seemingly simple game using the lens of behavioral science demonstrate the utility of the *scientification of games*, and hopefully encourage others to explore the hidden depths offered by this approach. In these ways, we can meet children, students and adults where they already are by leveraging the natural engagement with board games to allow them to discover hidden scientific knowledge about the way they think, decide and ultimately act.

■

[17] J. Kounios & M. Beeman, "The Aha! Moment: The Cognitive Neuroscience of Insight," *Current Directions in Psychological Science* 18 (2009), 210-216.
[18] R. C. Speelman, S. W. Whiting and M. R. Dixon, "Using Behavioral Skills Training and Video Rehearsal to Teach Blackjack Skills," *Journal of Applied Behavior Analysis* 48 (2015), 632–642.
[19] G. Brown, M. Tolman and M. Wallace, *Brass: Birmingham* [Board game] (Roxley Games, 2018).
[20] B. Cathala, *Kingdomino* [Board game] (Blue Orange, 2016).
[21] N. Dreksler & C. Spence, "A Critical Analysis of Colour—Shape Correspondences: Examining the Replicability of Colour—Shape Associations," *i-Perception* 10, No. 2 (2019), 1–34.
[22] C. Spence, "Crossmodal Correspondences: A Tutorial Review," *Attention, Perception & Psychophysics* 73 (2011), 971–995.
[23] Although blue book is historically a terms associated with car dealerships (see *Dealers Choice* [Board game] (Parker Brothers, 1974)).

Dr. Ben Dyson (he/him) is an Associate Professor in the Department of Psychology at the University of Alberta, Canada, and director of the Re:Cognition Lab. Ben’s work examines the intersections between empirical science and analog games, including the use of game spaces in revealing the dynamics of competitive decision-making, and the hidden scientific principles found within commercially available board and card games. The lab also develops entirely novel games that further help our understanding of human cognition. To this end, the lab is currently prototyping the computational card game Total Chaos, which explores the mysteries of negative numbers and zero.

Leo Baik is an undergraduate student with a BSc specializing in Psychology and finishing a degree in Secondary Education. He is currently a member of the Re:Cognition lab at the University of Alberta led by Dr. Ben Dyson. Games have been an important part of his life since his early childhood that has led to various unique experiences. He is interested in the application of various games in research and education as he believes that games have a lot of potential value in such fields that have not been fully unlocked or utilized. In particular, he believes that games that were designed for the purpose of being fun can be utilized and/or repurposed in the classroom and in the lab while being fun, engaging and intrinsically motivating for everyone involved.

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