






Establishing a New Computational Method to Predict Effects of Gaming: A Feasibility Study on Growth Mindset

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Abstract. We present a novel method for approximating potential psychological effects of video games on players utilizing computational text analysis and artificial intelligence. Focusing specifically on growth mindset – a psychological construct associated with learning and resilience – we analyze player-generated reviews on the Steam gaming platform. In particular, reviews were examined using a specifically developed growth mindset dictionary derived from key psychological texts and validated questionnaires. Utilizing over 1 million user-generated reviews across eight distinct game genres, we identified that puzzle, roguelike, and platformer games showed a higher prevalence of growth mindset-related terms when compared to genres that we considered unrelated to growth mindset (e.g., zen, cozy, walking simulator). This aligns well with a growth mindset meaning system, as these genres inherently involve setting objectives, exerting effort, learning from setbacks, and refining strategies through gameplay. In addition, exploratory BERTopic modeling identified four topics with a clear relation to the concept of a growth mindset. These topics emerged differentially across genres with a pattern like the one found with the dictionary, further corroborating our findings. These results confirm theoretical assumptions in the field with a new methodological approach, opening avenues for precisely targeted research on video game effects and informed selection of video game-based interventions.

Keywords: natural language processing · text mining · artificial intelligence · video games · growth mindset

1 Introduction

Video game effect research is usually concerned with investigating the associations with or consequences of gaming. These are usually studied using cross-sectional and intervention studies, for instance, by investigating the effects of a particular video game or genre by studying a video game exemplary for that genre. In fact, video games have been suggested to improve cognitive, emotional, motivational, and social skills [1–3].

Video games are frequently built on mechanics like coping with challenges and failure, or learning via trial and error, and developing corresponding skills [4]. For this

reason, it was suggested that video gaming can promote the development of a growth mindset [1, 5–7] by cultivating an incremental belief of intelligence and ability in players. The concept of a growth mindset thus simply reflects the belief that individuals can develop and enhance their personal abilities and talents through effort and learning [8]. Whereas perceiving intelligence or ability as unchangeable (= fixed mindset) can cause feelings of inadequacy, seeing them as a result of dedicated effort (= growth mindset) makes failure a cue for increased persistence and effort. The advantages of a growth mindset over a fixed mindset were extensively studied and supported by many research studies in the field of education [9, 10] as well as mental well-being [11].

Mindsets are assumed to be part of a broader “meaning system”, comprising a person’s goals, effort beliefs, attributions, and strategies, significantly shaping how individuals respond to setbacks and adversities [12]. In the context of gaming, such a “meaning system” might be more or less explicit. Certain games require the players to (i) set objectives to overcome obstacles (i.e., goals; e.g., setting goals aimed at improving a skill), (ii) evaluate the relationship between effort and outcome (i.e., effort beliefs; e.g., effort can lead to improvement), (iii) make sense of successes and failures (i.e., attributions; e.g., failure can be corrected by effort), and (iv) adopt various approaches to overcome obstacles (i.e., strategies; e.g., trying harder after failure). Hence, one might assume, that games more explicit with regard to the aspects of a “meaning system” are either more likely to be played by persons with a growth mindset or that some games may even provide an excellent environment to develop a growth mindset [1, 5, 7]. However, so far, strong empirical evidence supporting these notions is lacking.

One crucial problem for empirical research in this respect is the selection of potential games that might promote the construct or skills in question. This is exacerbated by the fact that games are becoming continuously more complex and can hardly be categorized into a single genre [13, 14]. Further, much of video game research is quickly outdated due to the fast pace of technological innovation and game development. In 2023, 30 new games were (on average) released daily just on Steam, amounting overall to 12.000 games released over the year (<https://steamdb.info>). Therefore, a so far missing, scalable method is required for identifying games that are potentially linked to or even affect the psychological construct in question. Systematic research on the effects of video games requires further a detailed understanding of their distinct characteristics, which is also potentially missed by relying on the current genre classification system [13].

To address these issues, we developed a new and scalable method using openly available user-generated reviews of video games. In digital gaming ecosystems like Steam, player-written game reviews can serve as a rich source of data on user experiences, game mechanics, and even mental health [15, 16]. That is, reviews not only reflect individual players’ preferences but also reveal underlying connections between games beyond their genres or tags. Drawing on the lexical hypothesis (e.g. [17]), which suggests that language reflects key personal traits, the analysis of natural language in reviews might reveal information about a game’s potential psychological impact.

Here, we apply modern computational text analysis methods to game reviews to isolate the most significant elements of gaming experiences. This approach could help narrow down the large annual output of video games to a smaller sample for in-depth

study of certain (psychological) effects. In the current study, we set out to examine the feasibility of our method to identify games that are likely related to a growth mindset.

2 Methods

2.1 Data Collection

The reviews were collected in the first week of March 2024. The Steam Review Explorer (<https://project.joshhills.dev/steam-review-explorer/>) was used to download reviews of games on Steam using the Steam API, resulting in a total of 1,125,185 reviews.

Table 1. Matching game genres to mindset meaning system. + indicates high relevance; ~ indicates some relevance; - indicates low relevance. Yellow/grey color represents game genres more/less likely to be related to a growth mindset.

	Mindset meaning system			
	Goal behavior	Effort beliefs	Attributions	Strategies
Game genres				
Roguelike	+	+	+	+
Puzzle	+	+	+	+
Platformer	+	+	+	+
Life simulations	~	~	~	~
Cozy	-	-	-	-
Zen	-	-	-	-
Walking simulation	-	-	-	-
Design & illustration	-	-	-	-

2.2 Selection Criteria and Data Preprocessing

The examined genres in this study were selected by categorizing the genres into the mechanisms of the mindset’s meaning system (Table 1). This procedure involved assessing which mechanisms of *goal behavior*, *effort beliefs*, *attributions*, and *strategies* [12] seem more/less relevant for certain game genres and could accordingly represent a growth mindset environment. The selection of genres was guided by the idea of identifying those that are strongly related to a growth mindset environment or preferred by players with a growth mindset. Growth mindset-related genres that were identified in this way were *roguelike*, *puzzle*, and *platformer*, as they all revolve around overcoming (difficult) obstacles and progress. Additionally, we considered *life simulation games* in the growth mindset category because of a preliminary finding in an unpublished survey study by the authors. Note that the mechanisms of the mindset’s meaning system do not appear to be overly relevant for this genre (see Table 1). Using the same procedure, a control group

consisting of four genres supposedly unrelated to a growth mindset was conceptualized. The genres included in the control group (neutral category) were *cozy*, *zen*, *walking simulation*, and *design & illustration*, as they do not heavily revolve around overcoming (difficult) obstacles and progress.

For each of the investigated genres, three, prototypical games were selected for analysis: *Roguelike*: The Binding of Isaac: Rebirth; Dead Cells; Enter the Gungeon; *Puzzle*: The Witness, BaBa is you; Talos Principle. *Platformer*: Ori and the Will of the Wisp, Getting Over It, Portal 2. *Life simulation*: Sims 4; Dinkum; Stardew Valley. *Zen*: Abzu; Journey; Gris. *Cozy*: Spiritfarer; KindWords; Unpacking. *Walking simulator*: Gone Home; Firewatch; What Remains of Edith Finch. *Design & Illustration*: Passpartout: The Starving Artist; House Flipper; House Flipper 2. These selected games should be rather consistent with the typical mechanics of their genre. To ensure sufficient data for analyses only games with at least 1500 reviews in English and a primarily positive overall rating were selected. This guarantees a minimum level of quality of the game.

During the reviews' preprocessing, the contractions within them were split, the reviews were converted to lowercase, emojis were converted to ASCII symbols, and special characters and digits were removed. All reviews with less than ten words were excluded to ensure that they could be meaningfully analyzed. After preprocessing, 563,047 reviews remained for subsequent analyses. *Stemming*, a natural language processing method in which words are reduced to their stem, was not done, to avoid a potential loss of information. This allows us to differentiate between different words of a common root word, such as "try" and "tried", which may be used in different contexts in the reviews, such as in the phrases "try something new" or "tried stardew valley".

2.3 Creation of the Growth Mindset Dictionary

Three different sets of texts served as the basis for the creation of a dictionary specifically tailored to the concept of a growth mindset. These three sets were: 1) the book "Mindset - The New Psychology of Success" by Carol Dweck [8]; 2) the transcripts of talks by Carol Dweck [23–25]; and 3) three (growth) mindset questionnaires [8, 26, 27]. These sets were analyzed using a frequency count of their respective unigrams to create a growth mindset-related dictionary. An n-gram is a sequence of n consecutive words, meaning that unigrams are a special case of n-grams with only one word. A researcher subsequently manually evaluated all relevant terms. Common proper names such as "Carol" and toponyms such as "Bronx" were excluded. In another round of inspection, the contextual usage of the remaining terms was evaluated by inspecting the frequencies of their bigrams in the reviews, to determine whether the terms (e.g., "challenge") were predominantly used in a manner related to growth mindset (e.g., "overcome challenge") or not (e.g., "no challenge"). Network graphs were created to visualize and inspect the most common co-occurrences of the terms of interest. This allowed for a more refined and precise construction of a growth mindset-related dictionary. Only terms showing a relation to the growth mindset concept through the analysis of their respective bigrams and network graphs were retained.

The final version of the context-adjusted growth mindset dictionary consisted of 31 unique terms derived from the book, transcripts, and questionnaires: abilities, ability,

become, challenge, challenges, challenging, constantly, develop, difficulty, fail, failure, feedback, goal, harder, improves, learn, learned, learning, mindsets, motivation, practice, problems, process, setbacks, skills, strategies, succeed, success, taught, try, trying.

2.4 Topic Modelling Using BERTopic

Topic Modelling using BERTopic [28] was performed on the reviews to determine whether growth mindset-related topics emerged from the data. This approach provided additional information on the extent to which growth mindset-related topics or themes were discussed in the reviews. Furthermore, it allowed a comparison of the frequency of the respective topics between the specified genres. BERTopic leverages state-of-the-art embedding models such as BERT (Bidirectional Encoder Representations from Transformers) to capture semantic information effectively and yield coherent and interpretable results. To ensure an equal influence of each genre on the topic modelling, 26 376 reviews were chosen randomly per genre resulting in 211 008 reviews ($26\,376 \times 8$) being analyzed during the topic modelling. The number 26 376 was chosen as it represents the number of reviews in the genre with the smallest number of reviews (i.e., *puzzle*), which is described in more detail in Sect. 3.1.

3 Results

The terms defined in the growth mindset dictionary were used to calculate the frequency of their occurrences, relative to the number of reviews in the respective genre. Hence, for each genre an average frequency of the growth mindset-related terms in the dictionary was calculated, which controls for differences in the number of reviews per genre. The results of parametric significance tests in this section were further checked with non-parametric equivalents, yielding qualitatively equivalent results.

3.1 Descriptive Results

Reviews of games in genres part of the growth mindset category (i.e., *platformer*, *life simulation*, *roguelike*; *puzzle*) were shorter ($mean = 52$ words, $SD = 88$) than reviews of games in the neutral category (i.e., *zen*, *cozy*, *walking simulation*, *design & illustration*; $mean = 72$ words, $SD = 103$). The average playtime ($mean = 195.99$ h, $SD = 433.47$) was higher in the growth mindset category than in the neutral category ($mean = 34.68$ h, $SD = 16.42$). Each genre yielded a different number of reviews: *puzzle* (26 376), *design & illustration* (27 833), *zen* (30 944), *cozy* (33 094), *walking simulation* (53 954), *roguelike* (89 191), *platformer* (107 592) and *life simulation* (194 063).

3.2 Differences between the Groups

A t-test was used to assess the differences in the occurrences of the terms in the growth mindset dictionary between the growth mindset-related genres and the neutral category, revealing a significant difference between the two categories $t(327123) = 31.865$, $p < .001$, $d = .086$. Reviews in the growth mindset category were associated with a higher average frequency of the terms defined in the growth mindset dictionary ($M = .265$, $SD = .791$) than reviews in the neutral category ($M = .201$, $SD = .611$).

3.3 Differences between the Genres

Statistical differences regarding the relative frequencies of the growth mindset-related terms between the genres were analyzed using an analysis of variance including the factor *genre* with the eight factor levels roguelike, platformer, puzzle, life simulation, zen, cozy, walking simulation, design & illustration. The analysis revealed significant differences between genres regarding the average frequency of growth mindset expressions $F(7,563039) = 1885, p < .001, \eta^2 = 0.023$.

Pair-wise differences between the genres were assessed using Tukey’s HSD method to compute p-values adjusted for multiple comparisons. All pairwise differences between the genres were significant except for two comparisons among genres of the neutral category (see Table 2). Notably, all growth mindset-related genres showed significantly higher values than genres in the neutral category in the pairwise comparisons, except for the life simulation genre which showed the lowest values (Fig. 1).

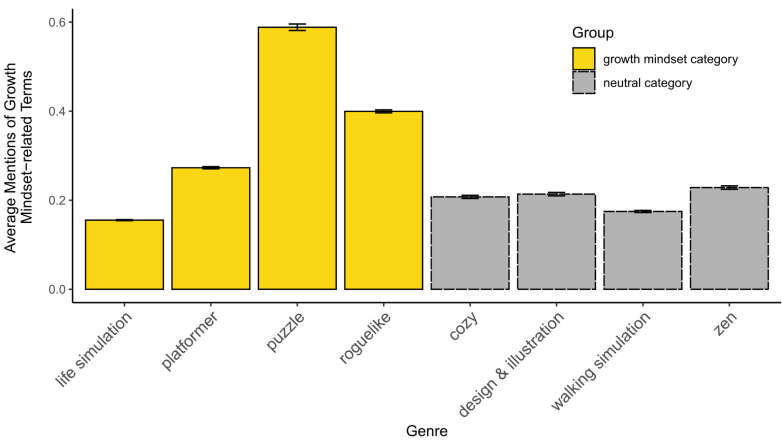


Fig. 1. Average Mentions of growth mindset-related expressions, depicted by genre. The absolute frequencies of growth mindset expressions per genre are relativized by the total number of reviews per genre. The standard errors are depicted by error bars.

3.4 Results of the Topic Modelling Using BERTopic

The topic modelling yielded 910 topics. Four out of the 910 identified topics via BERTopic showed a clear relation to the concept of growth mindset in an exploratory observation of these topics (Fig. 2). The number of reviews being classified as belonging to one of the four identified topics varied by genre: *platformer*: 303, *life simulation*: 39, *roguelike*: 491, *puzzle*: 274, *zen*: 17, *cozy*: 15, *walking simulation*: 8 and *design & illustration*: 23. Growth mindset-related topics are mentioned in 0.6% of reviews overall (1% in the growth mindset category and 0.06% of neutral category). These results serve as another indicator of the stability and validity of the findings of this paper. Moreover, the prevalence of the topics indicates that a discussion of growth mindset-related topics

Table 2. Effect sizes (Cohen’s d), highlighted by color, from highest (red) to lowest (blue), of the pairwise comparisons between the genres (upper triangle) and the corresponding *p*-values using Tukey HSD test (lower triangle). Three asterisks (***) signify *p*-values < .001. Platf. = platformer, Life S. = life simulation, D&I = design and illustration, W. Sim = walking simulation.

VS		Growth Mindset Category				Neutral Category			
		Puzzle	Rogue-like	Platf	Life S	Cozy	Zen	D&I	W. Sim
Growth Mindset Category	Puzzle		.179	.350	.680	.416	.384	.397	.512
	Roguelike	***		.138	.342	.207	.182	.197	.259
	Platf	***	***		.182	.084	.056	.075	.132
	Life S	***	***	***		-.097	-.134	-.109	-.037
Neutral Category	Cozy	***	***	***	***		-.032	-.010	.057
	Zen	***	***	***	***	.009		.022	.091
	D&I	***	***	***	***	.971	.238		.067
	W.Sim	***	***	***	***	***	***	***	

is not the focus of most reviews and underscores the value of employing computational text analysis for our approach rather than relying on manual qualitative analyses [16].

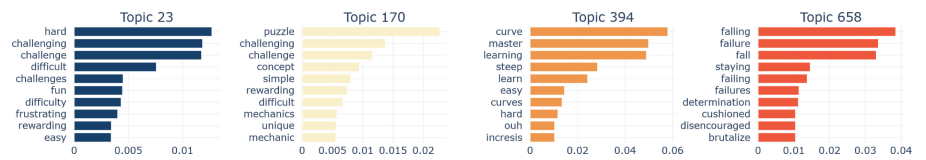


Fig. 2. Four identified growth mindset-related topics identified via exploratory BERTopic modelling. The x-axis of the topics depicts the representativeness of the term for the specific topic, calculated by a class-based TF-IDF (term frequency-inverse document frequency) procedure.

4 Discussion

The current study examined the feasibility of a new method to identify potential psychological effects of video gaming by analyzing user-generated reviews of video games on Steam using text mining and natural language processing. With the lexical hypothesis as our theoretical foundation, suggesting that language is a proxy for personal traits, we hypothesized that player reviews would reveal insights into how certain game genres might relate to or even foster a growth mindset.

Using the developed growth mindset dictionary, our results indicated that puzzle games had the highest frequency of growth mindset-related terms in player reviews, which supports the notion that this genre seems to be either particularly interesting for players with a growth mindset or even constitutes an environment to foster such a

mindset. Specifically, overcoming challenges in puzzle games often necessitates setting clear objectives and learning goals, the belief that (cognitive) effort can help overcome challenges, the attribution of failures to lack of effort than fixed abilities, and the flexibility to adopt new approaches/strategies (e.g., players would otherwise stop playing if a puzzle was not solved on first try). Furthermore, games of the genres roguelike and platformer exhibited a high presence of growth mindset terminology, second only to puzzle games. Roguelike games, for example, require learning goal-oriented gameplay and trial-and-error strategies where players are expected to learn and adapt from repeated failures, effectively requiring learning from setbacks. Similarly, platformers require players to refine their strategies and exert effort to navigate progressively challenging levels, fostering an environment potentially conducive to cultivating a growth mindset.

Despite not seeing a strong relevance of the mindset meaning system categories for life simulation games (see Table 1), we initially considered life simulation games as part of the growth mindset category because of preliminary correlational results of a survey study by the authors. However, life simulation games showed the lowest mentions of growth mindset-related terms. Yet, a potential link between life simulation games and a growth mindset cannot be ruled out due to their structure around task accomplishment and progress. However, such tasks are sometimes – at least partly – simulated (e.g., sending your Sims to work in Sims 4), and thus, motives for playing such games [29] might also differ considerably from puzzle or roguelike games.

The control game genres cozy, zen, walking simulation, and design & illustration revealed lower incidences of growth mindset language in reviews. This is in line with our assumption and categorization along the mindset meaning system categories (see Table 1). These genres are less likely or less explicit in challenging players to overcome obstacles or recover from failure, focusing more on creating a soothing atmosphere (i.e., zen, cozy) and emphasizing more on narrative exploration (i.e., walking simulations) or personal expression (i.e., design and illustration).

Overall, these results, which were qualitatively supported by the BERTopic model, seem to be in line with theoretical assumptions made in the field regarding the relationship between video gaming and a growth mindset [1, 5–7], demonstrating the usefulness of the current approach. However, it's important to note that by analyzing a large number of reviews, already very small effects result in significant differences between genres. In fact, almost every comparison of genres was significant. Thus, the reported effect sizes are necessary to contextualize the practical significance of these findings (Table 2). For instance, while our comparison between the grouped genres is significant – the effect size is negligible (Cohen's $d < 0.2$). This, however, is driven by our categorization of life simulation games as a growth mindset-related genre. In fact, we find the largest difference between puzzles and life simulation games. Importantly, considering the obtained small to medium effect sizes (Cohen's $d \sim 0.2$ – 0.5), it seems that puzzle and roguelike games seem to be more relevant for growth mindset as compared to games in our neutral control genres.

As this feasibility study set out to develop novel methods for supporting video game effect research, it is also confronted with some limitations. First and foremost, it is imperative to note that the mere mention of growth mindset-related terms in player reviews

does not necessarily indicate that the players themselves possess a growth mindset, or that the games with frequent mentions of such terms effectively promote the development of this mindset. This represents a significant challenge and needs to be carefully studied in future validation studies. Second, the dictionary constructed in this paper required substantial manual coding efforts and is not definitive. While the current outcomes suggest its utility, future studies should focus on its refinement and validation, such as examining additional genres and in-depth analysis of individual games. Further, expanding the dictionary to include bi- and trigrams, such as “overcoming this challenge,” could potentially enhance both accuracy and specificity. Additionally, with further advancement in automatic text processing and natural language processing, such word-specific dictionaries might no longer be necessary – increasing the approach’s scalability. However, a thorough understanding of the constructs/skills being investigated will remain crucial for guiding AI models, such as generative pre-trained transformers, which might still require manual coding (e.g., fine-tuning models).

Taken together, using this new approach, we found that games traditionally associated with overcoming challenges and performance improvements, such as puzzle and rogue-like games, yielded the highest mentions of growth mindset-related terms. Thus, applying computational text analysis to user-generated reviews might be feasible in determining how gaming preferences are related to latent psychological constructs. Importantly, this approach might also support video game effect research by filtering the large number of video games published each year to a more manageable subset of games for in-depth psychological examinations or identifying games potentially effective in cultivating specific skills, such as those associated with a growth mindset.

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