Good Newbie or Poor Newbie? Determinants of Video Game Skill Acquisition at an Early Stage

Kevin Koban(✉), Benny Liebold, and Peter Ohler

Institute for Media Research, Chemnitz University of Technology, Chemnitz, Germany
{kevin.koban,benny.liebold,peter.ohler}@phil.tu-chemnitz.de

Abstract. For several years now, game-based learning is deemed as one of the most innovative approaches in educational practice. Nevertheless, little research has been undertaken examining individual determinants of skill acquisition in video games. The presented paper offers empirical data from a nine-week training curriculum for novices in a racing simulation game. Regression analyses revealed that general video game experience and real-world driving experience significantly predicted both initial and later performance. Additionally, perceptual speed also became strongly influential after consistent training. Conversely, while achievement was affected at least occasionally by divided attention, focused attention and dispositions towards aggressive driving showed no effects. Although preliminary, these results provide evidence that those learners without certain beneficial skills may struggle with cutting-edge virtual learning scenarios. Thus, both individual assistance as well as early promotion of video game literacy might be needed to make full use of the potential of game-based learning.

Keywords: Skill acquisition · Individual differences · Game-based learning · Racing simulation games

1 Introduction

Video games have been found to be a promising asset for various learning domains. Recent meta-analyses provide evidence to support this claim by showing, for instance, that learning with serious games evokes substantial effects on declarative knowledge [1] just as simulation games contribute to a better understanding of complex issues [2] and various other video game genres stimulate certain cognitive skills [3, 4]. Most of all, these accomplishments in conjunction with short periods of training foster hopes to resolve important educational problems like the gender gap in science programs [5] or the low popularity of STEM disciplines [6]. Notwithstanding these promising findings, video games do not cause miraculous cognitive achievements. Just as with other technologies that are employed for learning purposes, both intentional and incidental learning with video games require long-term engagement of the learner in order to be effective. A fundamental determinant for such vital dedication lies in player's early performance. According to this, not only the fact that repeated failure is intensely frustrating [7], but also typical features providing rewards for superior initial performances determine whether prospective learners will make

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use of the learning potential [8]. It is therefore crucial to understand which individual attributes influence early performance in novel video game tasks [9]. The presented study investigates those influences in novices' skill acquisition within a virtual training with a racing simulation game. Our main research question was to test which individual characteristics predict early success in an unfamiliar video game task. Thereby, our research is tied to the game-based learning paradigm, in which it provides evidence from a motivational perspective.

2 Determinants of Skill Acquisition

Based upon the seminal work of Fitts and Posner [10] and Anderson [11] skill acquisition processes can be subdivided into three consecutive stages: a declarative stage, an associative stage, and a procedural stage. As stated by Shiffrin and Schneider [12], this delineated skill acquisition process can also be described as a continuous shift from controlled processing in the first stage towards automatic processing in the third stage. Thus, gaining declarative knowledge of a task, especially while performing, usually requires all cognitive resources available. After a considerable amount of training the exact same task can be executed automatically without any effort. Following these well-established frameworks, some authors had reasoned that certain learner characteristics as well as properties of the task have an impact on the progression of this skill acquisition process.

2.1 Personal Features Influencing Skill Acquisition

It is well known that learners with divergent initial capabilities approximate to a joint asymptote over the course of training [13, 14]. Additionally, a substantial body of research deals with the influence of individual cognitive abilities on skill acquisition [15–23]. Extending existing findings, the research group around Ackerman provides a framework for both sensorimotor and intellectual tasks. Based upon the three-staged models, Ackerman and his colleagues [13, 17–19] found evidence for distinct determinants in each acquisition stage. According to their model, general abilities without reference to the actual task affect performance within cognitive stage [20, 21]. Additionally, transferable schemes can have an impact on early achievement as well, if they do not interfere with task-specific requirements. This assumption follows the rationale that even though prior existing schemes might not be optimized for the specific demands of the task, its availability supports accomplishment.

As controlled processing becomes more and more unnecessary, the influence of general abilities and transferable schemes diminishes in the associative stage [22]. Instead, perceptual speed determining the capability to decide efficiently between existing procedures is growing in relevance. Thus, a fast and proper decision, which procedure among several mentally presented procedures needs to be activated determines performance in this skill acquisition stage [23]. Consequently, since these operations no longer occur in fully automatic processing, this effect declines towards third acquisition stage. As a result of automization, differences in diverse mental abilities become negligible in the final stage. Instead, psychomotor skills remain influential.

2.2 Task Properties Influencing Skill Acquisition

Besides learner characteristics, task properties influence the course of skill acquisition. For instance, as a result of the limitations of working memory [24], a high complexity extends the mental effort needed for encoding task requirements or organizing procedures that typically leads to slower improvements [25, 26]. Equally, oversimplified tasks sometimes enable to skip acquisition stages. Even more fundamentally, learning progress is affected by task consistency: Previous research demonstrated that the prototypical three-staged acquisition fully occurs only under the condition of high consistency with demands remaining the same throughout the training [12]. If, however, one or more essential features vary, learning progress will stagnate at some level of controlled processing without ever reaching full automization [21, 27, 28]. Since the distinct influence of certain learner characteristics depends on the current acquisition stage, task consistency strongly affects its effectiveness.

Sophisticated challenges combine both modes by keeping some elements constant while varying others. With regard to the current study, video games often contain repetitive tasks (e.g. operation of the input device) as well as variable tasks (e.g. the challenge itself). After sufficient practice stable elements therefore will be performed automatically, whereas ever-changing elements still have to be processed in a controlled manner.

3 Current Study

The presented study investigates skill acquisition within an unfamiliar video game task. To this end, the framework provided by Ackerman [17] serves as basis, which is utilized for a racing simulation game scenario. Based upon its emphasis in prior research [20], we expected that attention capacity positively predict individual performance in the first training session (H1a). Subsequently, this effect should diminish with consistent practice. Since steady exercise leads to automatic processing, we assumed that perceptual speed becomes a relevant positive predictor after sufficient training (H2). Otherwise, if an unfamiliar challenge is presented, it is expected that attention capacity will be a significant positive predictor at the second time of measurement as well (H3).

Due to apparent correspondences to other video game genres and real-world activities, several prior existing schemes might be relevant in racing simulation games. While genre-specific experience was controlled via selection of both real and virtual racing novices, some evidence supports the assumption that general video game experience also might affect performance in novel video game tasks. For instance, it is assumed that experienced video game players feel more motivated in game-like challenges than non-gamers. This motivational advantage then leads to superior performance [29, but see 30]. Additionally, video game experience might be linked to skills that improve the approach towards unknown problems [31, 32]. In the long term, those advantages of experienced gamers should decrease as feelings of self-efficacy [33] as well as more specialized strategies develop. Thus, we predicted that video game literacy positively only predicts initial performance (H1b).

To our knowledge, no studies investigating the relation between real world driving experiences and racing simulation performance have been presented so far. However, previous findings suggest that experienced drivers possess greater relevant procedural knowledge (e.g. towards the physics of driving or the racing line) and more reliable coping skills than novice drivers [34, 35]. As before, these schemes might be beneficial until more specialized procedures have been established. We therefore assumed that driving experience positively predicts performance solely at the first time of measurement (H1c).

Existing research on racing games focused primarily on its connection with risky driving behavior. Thereby, both longitudinal and cross-sectional studies found alarming effects [36–38] referring to action racing games. Yet, regarding racing simulations no correlation could be found [39–41]. In line with basic assumptions of the General Learning Model [42], these opposing effects can be interpreted as a consequence of differential in-game content. While action racers typically endorse dangerous driving manoeuvres, racing simulation games contribute to behaviors that are in compliance with realistic racing rules. Therefore, to be successful in a racing simulation, it is necessary to follow a more decent way of driving. For that reason, we expected that an individual disposition towards aggressive driving does not positively predict initial or later performance (H4).

Regardless of its popularity, several studies indicated that the use of authentic input devices is accompanied with a loss in performance [43–45]. McMahan and colleagues [45] speculated about possible reasons for these findings (e.g. the use of inadequate muscle groups or an inferior connection quality), but forgot to consider differences in experience with those devices. Even though other findings [43] mentioned this explanation, no evidence can be provided for lack of longitudinal data. Following this, we supposed that controller authenticity negatively predicts initial performance (H1d), but this impact diminishes over the course of training.

4 Method

We conducted an experiment following a $2 \times 2 \times 2 \times 2$ mixed design with controller authenticity (driving wheel vs. gamepad) and in-game vehicle (gokart vs. car) as between-subjects factors and time of measurement (first week vs. ninth week) and familiarity of the track (trained three times vs. trained eight times) as within-subjects factors. Participants with no noteworthy racing simulation game experience played *Gran Turismo 6* [46] on a Playstation 3 console for nine consecutive weeks. As part of a comprehensive study on novices' knowledge transfer, outcomes within vehicle groups were z-standardized to ensure comparability as both conditions used different tracks.

4.1 Participants

Because of rigid requirements towards subjects in the mentioned study on transfer learning, 71 out of 155 participants who completed the recruitment questionnaire were pre-selected according to several criteria (Table 1). Additionally, due to limited resources only 37 candidates could participate in the first cohort. For the study presented here, a total of 27 subjects were selected for the analyses due to a more rigorous exclusion of genre-experienced players. During training four of them aborted, so that the final sample of the first cohort consisted of 23 participants ($f = 15$, age: $M = 24.35$; $SD = 2.39$).

Table 1. Selection criteria for participants taking part in the training

Variable	Criterion
Driving licenses	must have car license must not have motor bike license
Physical fitness	$x \geq .2$ *
Gokart & racing car experience	$x \leq 2$ **
Racing interest	$x \leq 4$ **
Racing simulation game experience	$x \leq 1$ **
Risky driving attitude	$.1 \leq x \leq .6$ *
Reckless driving behavior	$.1 \leq x \leq .6$ *
Sensation seeking	$.1 \leq x \leq .8$ *
State anxiety	$x \leq .6$ *

Note: * scale from 0 to 1; ** Likert rating from 0 to 6.

4.2 Measures

Being part of a more extensive research project, this paper reports only those measures relevant for the purpose of this study. Attention capacity and perceptual speed were assessed using six different cognitive tests. To avoid multicollinearity only three of them were included after checking for significant intercorrelations. Thus, focused attention was measured by the d2 Test of Attention [47]. It consists of 14 lines filled with the letters d and p as well as zero to four dashed above and beneath every letter. Subjects have to highlight only the ds with two dashes while ignoring all the other combinations of letters and dashes (M_{pre} = 14.00; SD_{pre} = 2.45; M_{post} = 15.98; SD_{post} = 2.69). In addition, following numerous studies on action video games [e.g. 48] distributed attention was assessed via the Useful Field of View Test [49]. Therein, participants had to solve a decision task presented in the foveal area of the eye and an orientation task in the peripheral vision field simultaneously. The duration of both stimuli decreases until the subject could not give the right answer any longer (M_{pre} = .76 ms; SD_{pre} = .06; M_{post} = .76; SD_{post} = .04). In line with Ackerman and Beier [23], a straightforward letter decision task was conducted measuring perceptual speed. Two letters were presented at the same time. Each letter was either a vowel or a consonant in half of the cases. The task was to press the direction key on the keyboard that pointed towards the vowel as fast as possible, but only when both a vowel and a consonant appeared (M_{pre} = 828.44 ms; SD_{pre} = 226.09; M_{post} = 741.48 ms; SD_{post} = 185.49).

Participants' video game literacy and driving experience were assessed via single item self-report. We asked the participants for their general experience with video games on a 7-point Likert scale (M = 3.13; SD = 1.89) and for an estimate of their total amount of driven kilometers (M = 23482.61; SD = 33472.89). Furthermore, disposition towards aggressive driving was measured using an index with the risk-taking attitude and reckless driving behavior scales provided by Iversen [50]. Because one item of the reckless driving scale was eliminated due to a misleading description and low intercorrelations, the final index consisted of 27 items on a 5-point Likert scale (α = .838; M = 3.02; SD = .62). To measure performance we averaged the subject's best three lap times on each circuit. This mean value was calculated to get a more precise measure of the actual racing capability since novices usually lose time through multiple driving errors. The employed measure reflects a compromise between including the single best lap or each lap and was intended to be less vulnerable to outliers.

4.3 Procedure

Participants were recruited via university mailing lists for a longitudinal study about entertainment media use. After their selection, participants trained at one of two lab rooms equipped identically except for the input device. Training took nine consecutive weeks including 1-hour training per week. Pre- and post-measurements were conducted prior to the first and ninth training session. Cognitive tests were implemented in random order. After a short introduction, participants completed three races for 10 min each, yet of these only the second and third got evaluated. Racetracks were selected to provide a similar difficulty level. The manipulation of consistency was realized through different frequencies with which racetracks were practiced. While one of the evaluated tracks was trained only three times to remain rather unfamiliar (inconsistent condition), the other track was scheduled every week to become well known (consistent condition). Subsequently, participants were debriefed and paid off.

5 Results

The gathered data were analyzed using separate multiple linear regressions for both racetracks at both times of measure (Table 2). All of them used z-standardized performance as criterion and the above-mentioned influence variables as predictors.

Above all, data revealed that video game experience predicted initial performance significantly at the inconsistently trained track ($\beta = -.69$; $t(15) = -3.30$; $p < .01$) as well as marginally significant at the consistently trained track ($\beta = -31$; $t(15) = -1.86$; $p < .10$). Additionally, real-world driving experience ($\beta = -.40$; $t(15) = -2.54$; $p < .05$) and divided attention capacity ($\beta = -.47$; $t(15) = -2.85$; $p < .05$) turned out to be significant predictors of early performance in the consistent condition. Despite low test power, analyses provided support for hypothesis 1b and partial support for hypotheses 1a and 1c. Albeit not at a sufficient level of significance, it has to be noted that the effect of the input device pointed towards the predicted direction with authentic controllers affecting performance negatively ($\beta = -.34$; $t(15) = -1.61$; $p = .13$ at the inconsistently trained track and at the consistently trained track, $\beta = -.22$; $t(15) = -1.30$; $p = .21$). For the second time of measure we predicted that following inconsistent training attention capacity would be a relevant predictor of performance, whereas perceptual speed became influential after consistent practice. Unfortunately, our data yielded no effects of attention capacity. Thus, neither focused attention ($\beta = -.19$; $t(15) = -\ 1.01$; $p = .33$) nor divided attention (β = .14; t(15) = .75; p = .47) was significant. As expected, perceptual speed ability, however, turned out to be a significant predictor of performance at a consistently trained racetrack (β = .45; t(15) = 2.33; p = .03). Therefore, gathered data provided support for hypothesis 2, but not for hypothesis 3. Interestingly, video game literacy (β = −.58; t(15) = −2,92; p < .05 at the inconsistently trained track and β = –.39; t(15) = −1.88; p = .08 at the consistently trained track) and real-world driving experience (β = −.33; t(15) = –1.82; p = .09 at the inconsistently trained track and β = –.40; t(15) = −2.10; p = .05 at the consistently trained track) continued to be significant or marginally significant predictors, regardless of task consistency. Furthermore, the impact of controller authenticity turned out to be irrelevant after training with subjects now being negligible better with the driving wheel (β = .13; t(15) = .72; p = .48 at the inconsistently trained track and β = .11; t(15) = .56; p = .59 at the consistently trained track).

Table 2. Standardized regression coefficients for both times of measurement

Criterion	Predictor	β_{pre}	t_{pre}	p_{pre}	β_{post}	t_{post}	p_{post}
Lap time (inconsistent condition)	Video game literacy	–.685	–3.299	.005	–.583	–2.922	.011
	Driving experience	–.046	–0.233	.819	–.334	–1.820	.089
	Aggressive driving	–.033	–0.159	.876	.323	1.606	.129
	Input device	–.338	–1.607	.129	.131	0.718	.484
	Focused attention	.203	1.136	.274	–.047	–0.264	.795
	Distributed attention	.188	0.917	.373	–.192	–1.011	.328
	Perceptual speed	.123	0.541	.596	.140	0.746	.467
R^2 /adj. R^2		**.579 /.382**			**.583 /.389**		
Lap time (consistent condition)	Video game literacy	–.308	–1.856	.083	–.389	–1.881	.079
	Driving experience	–.398	–2.539	.023	–.400	–2.103	.053
	Aggressive driving	.258	1.568	.138	.104	0.502	.623
	Input device	–.219	–1.303	.212	.105	0.555	.587
	Focused attention	–.153	–1.066	.303	.018	0.099	.923
	Distributed attention	–.467	–2.848	.012	–.185	–0.942	.361
	Perceptual speed	.058	0.318	.755	.453	2.332	.034
R^2 /adj. R^2		**.731 /.605**			**.553 /.345**		

Note: Input Device (0 = Gamepad, 1 = Steering Wheel).

Additionally, we performed four equivalence tests to examine null hypothesis (H4) [51]. As expected, due to the low test power, equivalence tests were not significant at all performance measures (Table 3). Nevertheless, although not statistically relevant both regression analyses slightly indicated that an individual disposition towards aggressive driving correlated positively with achieved lap times. Thus, less aggressive race drivers tended to have faster lap times than drivers with a higher disposition for risky driving (e.g. $\beta = .32$; $t(15) = 1.61$; $p = .13$ on the inconsistently trained racetrack).

Table 3. Results of equivalence tests for aggressive driving for both times of measurement

Criterion	r_{pre}	p_{pre}	r_{post}	p_{post}
Lap time (inconsistent condition)	– .10	.428	.13	.470
Lap time (consistent condition)	– .02	.293	– .13	.470

6 Discussion

The presented study explored, which determinants had an impact on novices' skill acquisition in a racing simulation game. For this purpose, we conducted a nine-week virtual training curriculum examining whether individual characteristics predict game performance in the first and last training session. Further, we manipulated the frequency, with which certain racetracks were practiced assuming that familiarity with the task leads to changes in the required skill profile.

In sum, results were partially in line with the framework proposed by Ackerman and colleagues [17, 21]. In accordance with the literature, perceptual speed showed a strong effect within a well-known racetrack. Although the same amount of training was received overall, it remained an insignificant predictor in an unfamiliar task. This result supports the finding that mental abilities ensuring an efficient decision between several possible procedures became predictive of performance after consistent practice [23]. Unfortunately, since our training lasted only for nine weeks, we cannot provide evidence whether this impact will persist for a while or, as predicted by the framework, declines due to further automization. Prospective studies with long-lasting periods of training therefore have to investigate whether the framework fully applies in this context.

Additionally, prior existing schemes from video game use and actual driving experience were significant predictors not only, as expected, for initial performance, but also for later accomplishment. Thus, gamers outperformed non-gamers in a video game task, even though both were equally inexperienced with the specific video game genre. Existing literature provides several possible explanations. Whereas some authors argued for motivational benefits [29], others hold cognitive or strategic advantages accountable for this effect [31, 32]. Indicating a subtle distortion in measure, regular video game players might also have underestimated their experience by comparing it directly to their favorite video game genre. As consequence of this anchoring effect, gamers might actually be more experienced causing performance differences. Consequently, re-analyzing the collected data after the completion of the second cohort might shed some light on this subject. However, the surprisingly stable impact of video game experience can be explained by the moderate duration of training. Apparently, about six hours of training were not enough to override experience differences.

The positive impact of real-world driving experience can be interpreted in conjunction with the findings concerning divided attention. Interindividual differences in divided attention strongly affected performance in a single measure that took place at a dark and fairly confusing racetrack. Considering these requirements within a continuously changing setting, visual orientation becomes critical explaining the effect. In parallel, subjects might have taken advantage of a similar higher-order capacity associated with driving expertise. Several studies have demonstrated that expert drivers dispose more efficient visual scanning schemes than inexperienced drivers—particularly in demanding situations [52, 53]. This indicates that experienced drivers might have benefitted due to a constant need for orientation. Further research is needed to validate this interpretation among other possible explanations.

Focused attention revealed no significant effect. The reason behind this unexpected result might be related to task complexity. Some studies dealing with cognitively and sensomotorically demanding tasks demonstrated that harsh requirements easily overstrain novices at the outset [20, 22]. On this account, cognitive advantages like a superior focused attention capacity might be of little relevance until basic requirements are fully comprehended. The first time of measure might have been too early to detect an effect.

Furthermore, our analyses provided information about often-assumed deficiencies of authentic input devices [44, 45]. We argued that these disadvantages could be attributed to limited experience with those controls [43]. Our findings supported this argument as performance differences vanished after moderate practice. Since our investigation lacked statistical power, future longitudinal studies will have to validate our results. Additionally, in line with recent findings [39, 42], we found no significant effect of reckless driving. However, it should be noted that dispositions towards aggressive driving tended to predict performance negatively. Even though we cannot provide statistical support, this slight trend indicates that racing simulation games reward accurate driving rather than risky maneuvers.

Several limitations have to be mentioned. Firstly, owing to the fact that the results presented here only contain the first of two cohorts, the small sample size goes hand in hand with low test power. Therefore, only moderate to strong effects could accomplish reliable statistical analyses with acceptable type 2 errors. Additionally, as being part of a more comprehensive study on knowledge transfer, an irrelevant variation in condition had to be z-standardized and with this a possible distortion in data might have occurred. Furthermore, a nine week-long training with little more than six hours of practice and only two times of measurement does not claim to cover the whole skill acquisition process in detail. Thus, it remains unclear whether and how the influence of the chosen predictors changes between both measures or to a prolonged training.

7 Conclusion

The presented research examined the impact of individual features on novices' performance during a nine-week training curriculum using a racing simulation. Results suggest that general video game experience and real-world driving experience strongly influenced early task performance. Additionally, after some consistent training perceptual speed was rapidly growing in importance. Conversely, neither focused attention nor a disposition towards reckless driving predicted any virtual racing capability. These findings suggest that learners without those beneficial skills might struggle deeply with game-based learning scenarios. Being highly acclaimed in intentional and incidental learning contexts by now, this provides a challenge for educators ranging from immediate instructional support to early promotion of video game literacy.

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