Addictive Behaviors 97 (2019) 104–110

Contents lists available at ScienceDirect

Addictive Behaviors

journal homepage: www.elsevier.com/locate/addictbeh

An Assessment of the Validity of the Gamblers Belief Questionnaire☆

Kahlil S. Philander[a,b], Sally M. Gainsbury[b,*], Georgia Grattan[b]

[a] Carson College of Business, School of Hospitality Business Management, Washington State University, 915 North Broadway, Everett, WA 98201, United States of America
[b] Science Faculty, Brain and Mind Centre, School of Psychology, University of Sydney, Australia

HIGHLIGHTS

- Irrational beliefs can lead people to gamble beyond limits of affordability and contribute to harms.
- The Gamblers Belief Questionnaire is a 20-item test that can be self-administered.
- 184 US adults completed an online survey asesssing perception of skill and chance.
- GBQ items have validity in predicting distorted thoughts related to illusion of control and the gambler's fallacy.
- There is an opportunity to improve the parsimony of GBQ questions and the discriminant ability of its subscales.

ARTICLE INFO

Keywords:
Gamblers belief questionnaire
Cognitive distortions
Problem gambling
Illusion of control
Gamblers fallacy

ABSTRACT

Cognitive distortions in gambling are irrational thoughts that cause an individual to overestimate their level of control over the outcome of the game and diminish the role of chance. Due to their strong relation to gambling disorders, they are a particularly important characteristic to assess and understand in gamblers. Although numerous measures of gambling-related cognitive distortions exist, studies assessing criterion validity are scarce. In this study, we develop several tests of the Gamblers Belief Questionnaire (GBQ), a versatile and widely used scale. A sample of 184 U.S. adults was recruited through Amazon Mechanical Turk to complete an online study that included measurement of the GBQ and an assessment of the perceived role of skill and chance in various gambling and non-gambling activities. In addition to a confirmatory factor analysis of the scale, three novel validation tests were developed to understand whether the GBQ subscales can identify and discriminate measures of illusion of control and gambler's fallacy distortions. Our validation tests demonstrate that the scale does measure both distortions, providing information about gamblers' cognition that is unexplained by gambling problems, frequency of play, and demographics. Conversely, our analysis of the factor structure does not show good fit. We conclude that the GBQ measures gambling-related cognitive distortions, but there may be an opportunity to reduce the number of scale items and further refine precision of the two subscales.

1. Introduction

Cognitive distortions in gambling are irrational thoughts that cause individuals to overestimate their level of control over the outcome of the game and diminish the role of chance (Barrault & Varescon, 2013). Research on gamblers' cognitive distortions suggests that they are an important component to understand both normative and disordered gambling behavior (Hodgins, Stea, & Grant, 2011). Notably, evidence suggests that cognitive distortions lead to continued gambling despite significant financial loss (Goodie & Fortune, 2013; Walker, 1992), and play a causal role in the maintenance and development of gambling disorders (e.g. Blaszczynski & Nower, 2002; Goodie & Fortune, 2013; Hodgins et al., 2011; Jacobsen, Knudsen, Krogh, Pallesen, & Molde, 2007; Xian et al., 2008).

Identification of cognitive distortions is important to clinical practice in the treatment of gambling problems. Correcting distorted thoughts is often part of treatment protocols (Hodgins et al., 2011; Sharpe & Tarrier, 1993), and gamblers with more distorted thoughts are more likely to relapse from their recovery goals (Oei & Gordon, 2008). In a review of the role of cognitive distortions in treatment, Fortune and Goodie (2012) find that strategies focused on the correction of cognitive distortions, either alone or in conjunction with cognitive behavioral

☆ This work was supported by an Australian Research Council Discovery Early Career Research Award [DE1060100459] awarded to Dr. Sally Gainsbury. This research complied with APA ethical standards and was approved by the University of Sydney Human Research Ethics Committee.
* Corresponding author.
E-mail address: sally.gainsbury@sydney.edu.au (S.M. Gainsbury).

https://doi.org/10.1016/j.addbeh.2019.05.029
Received 5 March 2019; Received in revised form 25 May 2019; Accepted 25 May 2019
Available online 31 May 2019

therapies, generally show therapeutic success that is sustained across multiple follow-up periods.

Although several measures of gambling-related cognitive distortions are available, construct validation has tended to focus on face and content validity, rather than tests of criterion validity after scale development. Where studies have explored other dimensions of validity, analysis tends to be limited to correlations with measures of gambling problems (Goodie & Fortune, 2013), and covariance analyses of factor structure (e.g. Raylu & Oei, 2004; Smith, Woodman, Drummond, & Battersby, 2016). Despite cognitive distortions being well studied in gamblers, the related measures would benefit from more diverse assessments of validity.

In this study, we develop several novel tests to evaluate the criterion validity of the Gamblers Belief Questionnaire (GBQ) (Steenbergh, Meyers, May, & Whelan, 2002), and its associated Illusion of Control (GBQ-IoC) and Luck/Perseverance (GBQ-LP) subscales. We focus on the GBQ due to its popularity in the literature and the versatility of its use. In a review of gambling cognitive distortions scales, only one other scale had more published studies linking the measure to gambling disorders, and that scale was designed for use with video lottery terminal players only (Goodie & Fortune, 2013).[1] Our tests examine how GBQ scores are related to differences in perceived skill and chance involved in dissimilar game types and lengths of play. As part of our tests, we control for gambling problems and frequency of play to demonstrate that the scale provides non-redundant information about gamblers' cognition. We also test the validity of the GBQ's factor structure through a confirmatory factor analysis.

Due in large part to role that distorted thinking is believed to play in the etiology of gambling disorder (Blaszczynski & Nower, 2002), improving psychometric understanding of cognitive distortions would be a valuable contribution for treatment, prevention and research. A well-validated tool would help inform related modifications and refinements to treatment, product designs, public health communications, and other topics of individual and societal interest. In addition, emerging technologies like virtual reality, mobile gambling, and video game-like products are changing the nature of gambling products, creating an increasing need to validate a broader psychometric measure that can assess cognitive distortions across a range of applications (Gainsbury & Blaszczynski, 2017; King, Gainsbury, Delfabbro, Hing, & Abarbanel, 2015).

1.1. Cognitive distortions in gambling

Distortions present themselves in gamblers through more than one phenomenon. One source of bias in cognition is the use of heuristics, such as availability or representativeness. The frequently cited "gambler's fallacy" is an error in representativeness, where a gambler believes that independent events are correlated as part of reaching a long-run average. For example, a gambler may believe an odd number is more likely to land on a roulette wheel after several consecutive even numbers have occurred, despite the events being statistically independent. The gambler's fallacy is demonstrated broadly across a range of games (e.g. Clotfelter & Cook, 1993; Sundali & Croson, 2006; Xu & Harvey, 2014), and is found to be predictive of gambling disorder risk (Holtgraves, 2009).

Non-heuristic cognitive distortions also present themselves in gamblers. The most noteworthy example is the illusion of control. An illusion of control occurs when a player believes that her probability of personal success is higher than the objective probability of success (Langer, 1975). Experimental studies have demonstrated these thoughts among gamblers in many different scenarios (Davis, Sundahl, Lesbo, 2000; Dunn & Wilson, 1990; Ladouceur & Maryland, 1987; Toneatto, Blitz-Miller, Calderwood, Dragonetti, & Tsanos, 1997). For a thorough review of gambling-related cognitive distortions and related measures, see related works by Fortune & Goodie (Fortune & Goodie, 2012; Goodie & Fortune, 2013).

Langer (1977) discusses two skill and luck concepts that are important to understand cognitive distortions in the context of games. The first is that individuals may not make distinctions between skill and chance elements because of their simultaneous presence in many activities. Skill and luck are often quite closely associated in subjective experiences, which makes them hard to distinguish and reinforces illusions of control. For example, a winning hand in poker that may be attributable to luck, skill, or a combination of the two factors. Second, Langer states that individuals have a general incentive in their lives to develop a mastery over their environment, and that complete mastery would include an ability to 'beat the odds'. She notes that individuals' attempts to achieve competency are incompatible with viewing chance events as uncontrollable. This may partially explain why individuals rely on heuristics for prediction, which subsequently reinforce cognitive distortions like the gambler's fallacy.

1.2. Gamblers belief questionnaire

The GBQ is a self-administered scale used to assess gambling-related cognitive distortions. The scale was originally validated through five studies described in Steenbergh et al. (2002). The first study included a review of literature to create a list of items to assess general gambling-related cognitive distortions, which was then reviewed by three experts in related fields. The second study used responses from a sample of community members and undergraduate students to conduct an exploratory factor analysis on the items, leading to a 21-item scale with two factors. The third study assessed reliability with an undergraduate sample, whose test/re-test correlations were examined after a two-week period, showing a correlation of 0.77. The fourth study demonstrated convergence of GBQ scores with measures of gambling disorders in community and student samples, and the fifth study demonstrated that the scale was unrelated to a measure of social desirability in the second study's student sample. Validated translations of the scale were subsequently produced in Spanish (Winfree, Meyers, & Whelan, 2013), Chinese (Wong & Tsang, 2012), and Italian (Marchetti et al., 2016). The scale was revised to 20-items in a later study of treatment-seeking disordered gamblers, based on item content consideration (Winfree, Ginley, Whelan, & Meyers, 2015). We evaluate the 20-item version of the scale.

Items are measured on a 7-point scale (1 = strongly agree, 7 = strongly disagree), which are reverse coded and summed. Higher scores indicate higher levels of cognitive distortions. There are two subscales: 1) An 8-item illusion of control construct; and 2) a 12-item luck/perseverance construct. The GBQ-IoC is broadly composed of illusion of control related questions and the GBQ-LP is broadly composed of gambler's fallacy related questions, although some questions cross-loaded at typical threshold scores (Hair, Black, Babin, Anderson, & Tatham, 2010).

Cronbach's alpha was not reported in Steenbergh et al. (2002), but Mattson, MacKillop, Castelda, Anderson, and Donovick (2008) estimate GBQ reliability with an α of 0.93 in a sample of college undergraduates. The GBQ-IoC α was 0.89 and the GBQ-LP α was 0.94 in the same study. Winfree et al. (2015) estimated the GBQ α at 0.87 in a clinical sample of treatment seeking gamblers. The Spanish-translated version of the GBQ shows similar psychometric properties, with a valid factor structure with some cross-loadings, and high reliability scores with a GBQ α of 0.95, a GBQ-IoC α of 0.86 and a GBQ-LP α of 0.96 (Winfree et al., 2013).

The only confirmatory factor analysis (CFA) was conducted by

[1] The authors of the review also note, "[the GBQ] has been investigated in the most extensive number of studies, with a large collective N coming from a large diversity of laboratories, a large effect size, and a narrow 95% CI."

Pilatti, Cupani, Tuzinkievich, and Winfree (2016) on the 20-item scale. They report acceptable fit, but the results are difficult to interpret as no likelihood ratio statistics were reported. Based on the factor structure of the GBQ, we propose our first hypothesis:

H1. A two-factor structure described by the GBQ-IoC and the GBQ-LP fits gambler responses to the 20-item questionnaire.

Our subsequent hypotheses are based on the theoretical and empirical evidence of cognitive distortions in gambling and the presence of illusion of control and gambler's fallacy questions on the GBQ. To provide a point of comparison, the study included a focus on a new form of gaming machine, skill-based gaming machines (SBGMs). In contrast to slot machines, whose outcomes are completely determined by chance, SBGMs are games of mixed skill and chance that incorporate an element of skill into traditional EGM mechanics. Currently only available in a few gambling jurisdictions within the U.S., SBGMs allow players to increase their chances of winning or the size of the payout depending on their performance in the game (Fisher, 2016). We derive the following hypotheses through a deductive process to assess the criterion validity of the GBQ-IoC and the GBQ-LP:

H2a. The GBQ-IoC is positively related to the difference in perceived skill of games of only chance versus the perceived skill of games of only skill.

H2b. The GBQ-LP is unrelated to the difference in perceived skill of games of only chance versus the perceived skill of games of only skill, after controlling for the GBQ-IoC.

Explanation: Individuals who view games of only chance as closer in perceived skill to games of only skill will have higher estimated levels of illusion of control, relative to other respondents. After controlling for shared variance, there should be no relationship with measures of gambler's fallacy since attributions to repeated play would be removed by differencing perceptions.

H3a. The GBQ-IoC is positively related to the difference in perceived skill of games of only chance versus the average perceived skill of games of mixed skill and chance.

H3b. The GBQ-LP is unrelated to the difference in perceived skill of games of only chance versus the average perceived skill of games of mixed skill and chance, after controlling for the GBQ-IoC.

Explanation: Individuals who view games of only chance as closer in perceived skill to games of mixed skill and chance, will have higher estimated levels of illusion of control, relative to other respondents. After controlling for shared variance, there should be no relationship with measures of gambler's fallacy since attributions to repeated play would be removed by differencing perceptions of the two games.

H4a. The GBQ-LP is positively related to the difference in perceived likelihood of winning on a game determined by chance over relatively long period of time versus a relatively short period of time.

H4b. The GBQ-IoC is unrelated to the difference in perceived likelihood of winning on a game determined by chance over relatively long period of time versus a relatively short period of time, after controlling for the GBQ-LP.

Explanation: In a game of chance with negative expected value, the probability of winning will fall with more wagers over time. Individuals who view skilled players as more likely to win money over a long period of time than a short period of time will therefore have higher levels of gambler's fallacy related cognitive distortions. After controlling for shared variance, there should be no difference in illusion of control, as the comparison is within the same game.

2. Methodology

2.1. Participants

A sample was recruited using Amazon Mechanical Turk, an online web-based platform for human executed tasks. Ethics clearance was granted by [REDACTED] Human Research Ethics Committee. Participants were restricted to those with an MTurk approval rating of at least 95%, consistent with practices adopted in previous research (Goodman, Cryder, & Cheema, 2013). Participation was restricted to English speaking North Americans of the legal gambling age (21 years of age or older) that had lived in or visited the jurisdictions that contain SBGMs (Nevada, New Jersey, Connecticut, and California) in the past 12 months in order to recruit participants who may have had experience with this gambling activity.

Sample size is an important feature of this study. A sufficiently large sample size is a necessary condition to reject some null hypotheses in support validation arguments. Conversely, some tests of model fit are sensitive to sample size and will produce Type I errors if samples are too large. For example, the likelihood ratio test is noted to almost always be statistically significant if sample sizes are larger than 400 observations (Kenny, 2012; Satorra & Saris, 1985). To inform sample size selection, we use the *Computing power and minimum sample size for RMSEA* tool (Preacher & Coffman, 2006) to calculate model power assuming an alpha of 0.05 and desired power of 0.8. We use the root mean squared error of association (RMSEA) from Winfree et al. (2015) as our null RMSEA and MacCallum, Browne, and Sugawara's (1996) value of 0.05 as 'good' fit as our alternative RMSEA. Based on those figures, the tool recommends a minimum sample of 169 observations. A total of 232 respondents were recruited; 47 respondents were removed from analysis due to failing at least one of two attention checks, and one was removed for completing the survey in an unfeasibly short time period. There was no missing data as all questions required a response. In total, responses from 184 individuals were used in this study.

Respondents were disproportionally male (68%); all had a high school diploma or equivalent, and 63.59% had a bachelors degree or higher; and most were employed full-time (78.26%), with a small number of part-time/casually employed (9.24%), unemployed (4.89%), student (3.26%), retired (1.63%), or other employment status (2.72%) respondents. They were diverse in their reported gambling problems: non-problem (45.11%), low-risk (26.09%), moderate-risk (7.07%), and problem (21.74%). In Table 1, we summarize respondent characteristics and their assessment of relative skill in games related to this study.

Table 1
Respondent summary statistics.

Variable	Count	Mean	Std. dev.	Min	Max
Age	184	34.02	9.29	21	69
Slot Play Frequency	184	2.43	1.33	1	6
SBGM Play Frequency	184	2.04	1.51	1	6
Perceived Skill in Chess	184	80.23	30.67	0	100
Perceived Skill in SBGMs	184	48.52	27.28	0	100
Perceived Skill in Slots	184	10.07	14.65	0	74
PGSI Score	184	4.29	6.34	0	24
GBQ	184	71.10	29.48	20	132
GBQ-IoC	184	31.73	11.59	8	53
GBQ-LP	184	39.37	19.08	12	79

Note. Frequency variables are labeled responses from 'not at all' to 'daily' regarding, "In the past 12 months, how often have you typically gambled on [Game]?"

2.2. Design

Through an online survey supplemented with media, respondents were shown videos of electronic gaming machines (EGMs) to facilitate a baseline understanding of slot machines and SBGMs. They were then asked a series of questions about perceived skill and chance in games (both gambling and non-gambling).

Respondents were asked to simultaneously order eight different gambling and non-gambling games (e.g. chess) along a 100-point scale from *all chance* (0) to *all skill* (100) (Perceived Skill). They were also asked questions about the extent to which they agreed that players of greater skill would be more likely to win money playing specific gambling games. Respondents were then asked several demographic questions, gambling frequency questions, and were administered the GBQ and the Problem Gambler Severity Index (PGSI, Ferris & Wynne, 2001). We use classification categories from Currie, Hodgins, and Casey (2013). Two attention check items were distributed in separate sections of the survey to identify non-conscientious or random responders (e.g., "please choose 'somewhat disagree' as your response to this question") (Marjanovic, Struthers, Cribbie, & Greenglass, 2014).

2.3. Analysis

To test the H_1, we estimate a confirmatory factor analysis (CFA) model of the GBQ factors (Steenbergh et al., 2002) using Stata/MP 15.1. We assess model fit using a likelihood ratio test, the RMSEA the comparative fit index, and the Tucker-Lewis Index.

To test H_{2a} and H_{2b}, we compute the difference in ratings for chess and slot machines using the 100-point chance/skill rating scale, in comparison to mean responses:

$$\Delta^{Slot-Chess} = (x_i^{slot} - \bar{x}_i^{slot}) - (x_i^{chess} - \bar{x}_i^{chess}) \quad (1)$$

where, x_i^j refers to the score given by respondent '*i*' to activity '*j*' and $\bar{x}_i^j$ refers to the sample mean of that activity. Intuitively, we measure whether respondents view chess and slots as close (smaller values) or far (larger values) in relative skill. Larger values of $\Delta^{Slot-Chess}$ are interpreted as higher levels of cognitive distortions.[2] We then estimate a set of ordinary least squares (OLS) models that successively regress $\Delta^{Slot-Chess}$ onto GBQ-IoC, GBQ-LP, and other controls. This set of models tests the criterion validity of the GBQ-IoC and the discriminant validity of the GBQ-LP by assessing their explanatory power against two activities that can objectively be view as high in chance (slots machines) and high in skill (chess).

To test H_{3a} and H_{3b}, we exploit similarities and differences in two forms of EGMs, slot machines and SBGMs. After respondents were shown sample demo videos of a representative slot machine and a representative SBGM, which depicted the user experience of playing the games, they were asked questions on perceived skill and chance for the respective game shown. The SBGMs game has an actual element of skill that is shown in the video, while the slot machine has no element of skill and is not described with any skill element. The order of viewing for the videos was randomized for respondents. On a five-point Likert scale ranging from 'strongly disagree' (1) to 'strongly agree' (5), respondents are asked whether, "A player of greater skill is more likely to win money on the [slot machine | skilled game gambling machines] over one hour".

We compute differences in responses regarding slot machines ($m = 2.24$, $sd = 1.33$) and responses regarding SBGMs ($m = 4.19$, $sd = 0.88$), from mean responses and each other. Formally,

$$\Delta^{Slot-SBGM} = (x_i^{slot} - \bar{x}_i^{slot}) - (x_i^{game} - \bar{x}_i^{game}) \quad (2)$$

[2] While the mean differencing in Eq. (1) only impacts the constant term in the regression models, we use it in our design as it allows for a more intuitively understandable formulation.

We estimate a series of ordinary least squares (OLS) models that regress $\Delta^{Slot-Game}$ onto GBQ-LP, GBQ-IoC, and other controls. We hypothesize respondents with higher illusions of control will view slots as closer-to, or potentially greater than, SBGMs in skill. We hypothesize no relationship between $\Delta^{Slot-Game}$ and GBQ-LP, after controlling for GBQ-IoC, since there is no time dimension in the comparison to implicate the gambler's fallacy. This set of models tests the criterion validity of the GBQ-IoC and the discriminant validity of the GBQ-LP by assessing their explanatory power against two activities that can objectively be view as high in chance (slots machines) and mixed-skill and chance (SBGMs).

To test H_{4a} and H_{4b}, we ask respondents about their perceptions of SBGM outcomes over relatively short (one hour) and long (50 h) periods of time. After being shown the SBGM demo video, respondents were asked to rate the extent to which they agreed that, "A player of greater skill is more likely to win money on the skilled game gambling machine over [1 or 50] hours" on a five-point Likert scale from 'strongly disagree' (1) to 'strongly agree' (5). We compute differences reported scores over one-hour ($m = 4.19$, $sd = 0.88$) and fifty hours ($m = 4.28$, $sd = 0.85$), and from mean responses. Formally,

$$\Delta^{1h-50h} = (x_i^{slot1h} - \bar{x}_i^{slot1h}) - (x_i^{slot50h} - \bar{x}_i^{slot50h}) \quad (3)$$

We estimate a series of ordinary least squares (OLS) models that regress Δ^{1h-50h} onto GBQ-LP, GBQ-IoC, and other controls. We hypothesize respondents with higher gambler fallacies to view longer periods of play as involving more skill, which would be indicated by a positive and significant coefficient on GBQ-LP. We hypothesize no relationship between $\Delta^{50h/1h}$ and GBQ-IoC in the second stage model, after controlling for GBQ-LP. Differencing of one-hour and fifty-hour responses should remove effects of illusion of control, as they are questions relating to the same game, leaving only differences in the related time dimension, which should reveal cognitive distortions around luck and the role of persistence.

3. Results

Fig. 1 illustrates the CFA model. We find the GBQ factors do not fit this data well. From our likelihood ratio test, we reject the assumption that the model fits as well as the saturated model, $\chi^2(169) = 518.14$, $p < 0.001$. Our measure of population error fails to reach cutoff values for mediocre fit, RMSEA = 0.11, > 0.08 (MacCallum et al., 1996). The lower bound rejects the hypothesis that the fit is close 90% CI, lower bound = 0.10, > 0.05, and the upper bound fails to reject the assumption of poor fit, 90% CI, upper bound = 0.12, > 0.10 (Browne & Cudeck, 1992; StataCorp, 2017). The baseline fit indices are not close to the desired value of 1.00 (Bentler, 1990; StataCorp, 2017), Comparative Fit Index = 0.89, Tucker-Lewis Index = 0.88.

Our constructed tests show better validity. As shown in Table 2, we find evidence supporting H_{2a}. Perceived differences in chess and slot skill are found to be predicted by GBQ-IoC scores, even after controlling for gambling problems, play frequency, and demographics (model 3). We also find PGSI group membership to be related to the difference score. However, we fail to find support for H_{2b}, as the GBQ-LP is noted to have a statistically significant effect in all models (4–6).

Our tests of H_{3a} and H_{3b} are similar. As shown in Table 3, we find evidence supporting H_{3a} but not H_{3b}. Differences in perceived slot and SBGM skill are differentiated by relative scores on the GBQ-IoC, but GBQ-LP are also significant when the GBQ-IoC and other controls are included in the model. Notably, the GBQ-IoC is not significant in those models (4–6).

In our tests of H_{4a} and H_{4b}, we find evidence in support of both hypotheses. After controlling for gambling problems and play frequency (models 2 and 3), we find evidence that GBQ-LP is related to perceived differences in outcomes on SBGM over one hour versus 50 h. In models 4–6, we fail to find evidence that GBQ-IoC is related to the same outcome measure when we control for GBQ-LP, supporting H_{4b}. We also

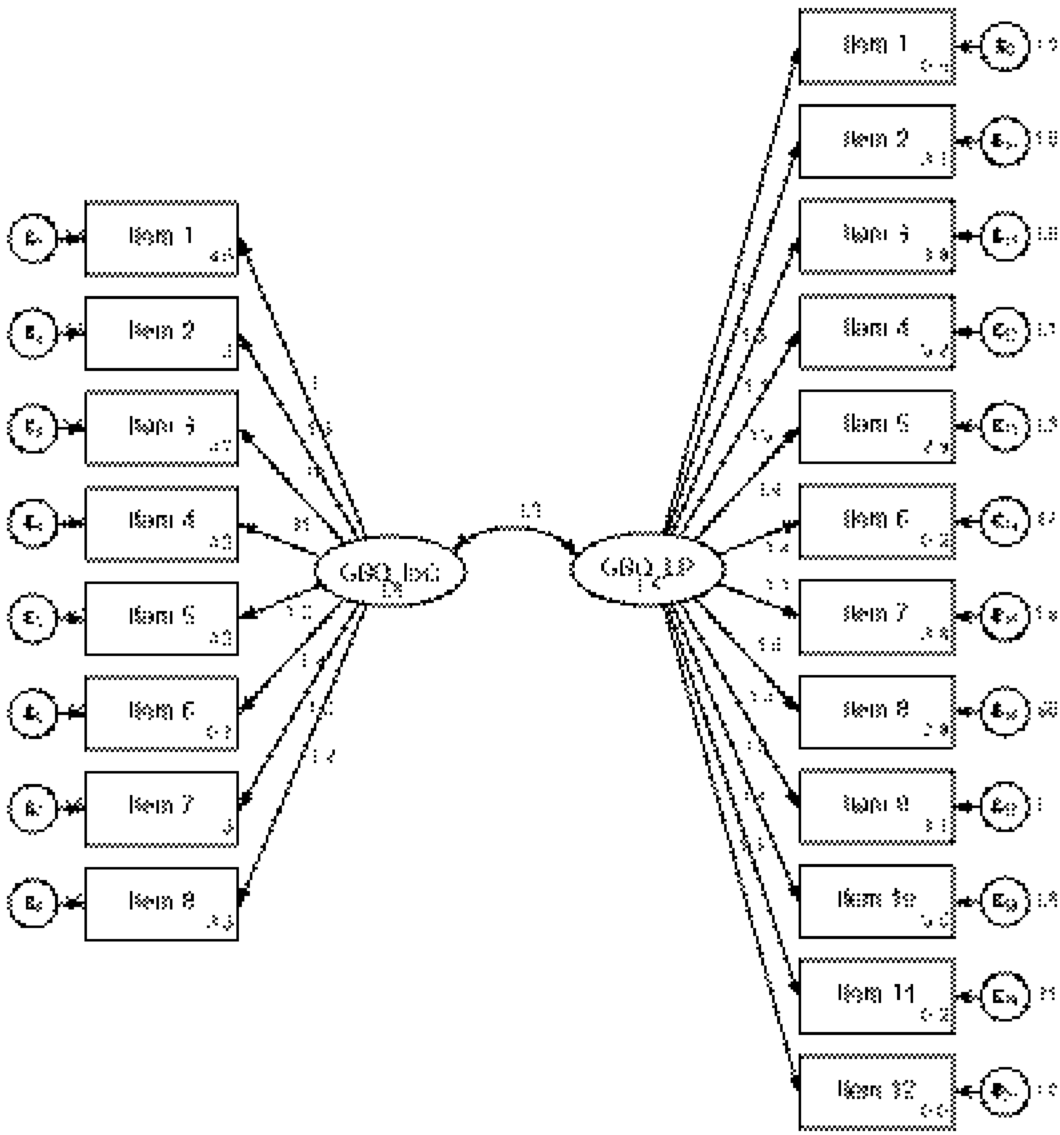

Fig. 1. Confirmatory factor analysis model results (n = 184).

find PGSI group membership to be related to the difference score (Table 4).

4. Discussion

As a feature of both the normative and disordered gambling experience, cognitive distortions are an important phenomenon to understand motivations, behaviors, and appropriate treatment protocols. In this study, we designed three validation tests and used one statistical-based approach to evaluate one of the most widely used measures of gambling-related cognitive distortions, the GBQ. Overall, our results suggest that the GBQ items have validity in predicting distorted thoughts around gambling activities related to illusion of control and the gambler's fallacy. This relationship is generally robust, showing a measurable effect with our measures even after controlling for frequency of play, sex, age, and education levels. It further demonstrates to be non-redundant to measures of gambling problems, as the both subscales show a measurable relationship with our dependent variables when we control for PGSI categories.

The absence of evidence supporting H_{2b} and H_{3b} showed similar patterns and may be related to the same phenomenon. In both cases, GBQ-LP effects were significant and GBQ-IoC were generally not, when it was hypothesized the opposite may be the case. It is worth considering whether the perceived latent constructs represented by the two subscales are meaningfully independent, or are related to a wider cognitive distortion attribute.[3] Ejova, Delfabbro, and Navarro (2015) provide some evidence that there is an underlying process or belief structure that is connected to vulnerability of specific gambling-related beliefs, which would help explain these results. Relatedly, in Steenbergh et al. (2002) and Winfree et al. (2013), multiple items cross-loaded onto both factors at the 'rule-of-thumb' value of 0.3 or more (Hair et al., 2010), suggesting that aspects of the subscales may be conflated. Again, this could lead in part to the discrimination challenges we observed in our some of tests.

Based on our study and others, there is some evidence that there is an opportunity to improve the parsimony of GBQ questions and the discriminant ability of its related subscales. The GBQ generally performed poorly across a range of test statistics in our CFA, despite our efforts to identify an appropriate sample size of regular gamblers. This is similar to the results from Winfree et al. (2015), which found poor test statistics in a CFA of the GBQ in a clinical sample of respondents. A simplification of the model by the removal of some items and

[3] We thank an anonymous reviewer for this insight.

Table 2
OLS regressions of perceived skill difference in slots and Chess ($DV: \Delta^{Slot-Chess}$).

	(1)	(2)	(3)	(4)	(5)	(6)
GBQ-IoC	1.70***	0.46**	0.45*	−0.54*	−0.13	−0.11
	(0.21)	(0.17)	(0.18)	(0.27)	(0.24)	(0.25)
GBQ-LP				1.62***	0.65**	0.61**
				(0.21)	(0.23)	(0.23)
PGSI Low		−1.69	−2.59		−3.99	−4.77
		(4.15)	(4.22)		(4.14)	(4.20)
PGSI Moderate		6.12	7.01		2.72	3.99
		(10.9)	(11.8)		(11.4)	(12.2)
PGSI Problem		68.8***	66.1***		60.5***	58.4***
		(12.9)	(12.9)		(13.7)	(13.6)
Slot Play Freq.	No	Yes	Yes	No	Yes	Yes
Sex	No	No	Yes	No	No	Yes
Age Categories	No	No	Yes	No	No	Yes
Education	No	No	Yes	No	No	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
N	184	184	184	184	184	184
R^2	0.24	0.55	0.57	0.41	0.57	0.59
Adjusted R^2	0.23	0.53	0.53	0.40	0.54	0.54

Note. PGSI Low are scores from 1–4; PGSI Moderate are scores from 5 to 7; and PGSI Problem are scores from 8+. Slot Play Freq. is slot play frequency. Age categories are ten-year bands beginning at '20'. Heteroskedasticity robust standard errors in parentheses.

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 3
OLS regressions of perceived skill difference in slots and SBGMs ($DV: \Delta^{Slot-SBGM}$).

	(1)	(2)	(3)	(4)	(5)	(6)
GBQ-IoC	0.08***	0.05***	0.06***	0.01	0.01	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
GBQ-LP				0.05***	0.05***	0.04***
				(0.01)	(0.01)	(0.01)
PGSI Low		−0.08	−0.14**		−0.27	−0.33
		(0.26)	(0.26)		(0.25)	(0.26)
PGSI Moderate		0.30	0.32		0.04	0.06
		(0.40)	(0.40)*		(0.40)	(0.41)
PGSI Problem		0.37	0.55		−0.30	−0.13
		(0.40)	(0.43)		(0.49)	(0.50)
Slot Play Freq.	No	Yes	Yes	No	Yes	Yes
SBGM Play Freq.	No	Yes	Yes	No	Yes	Yes
Sex	No	No	Yes	No	No	Yes
Age Categories	No	No	Yes	No	No	Yes
Education	No	No	Yes	No	No	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
N	184	184	184	184	184	184
R^2	0.34	0.44	0.47	0.45	0.49	0.51
Adjusted R^2	0.34	0.40	0.40	0.45	0.44	0.44

Note. PGSI Low are scores from 1–4; PGSI Moderate are scores from 5 to 7; and PGSI Problem are scores from 8+. Slot Play Freq. is slot play frequency. Age categories are ten-year bands beginning at '20'. Heteroskedasticity robust standard errors in parentheses.

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

reexamination of the factor structure may actually improve related performance, in addition to the benefit of reducing questionnaire length. Reliability statistics from past studies further support the notion that the GBQ could be made shorter. For example, Winfree et al. (2013) and Mattson et al. (2008) both found reliability values above $\alpha > 0.9$ for the GBQ. Values that high suggests there may be redundancies in the scales, and that fewer items could be used (Tavakol & Dennick, 2011).

Table 4
OLS regressions of perceived impact of skill on SBGM outcomes over time ($DV: \Delta^{1h-50h}$).

	(1)	(2)	(3)	(4)	(5)	(6)
GBQ-IoC				−0.002	−0.006	−0.001
				(0.006)	(0.006)	(0.006)
GBQ-LP	0.004	0.009*	0.010**	0.005	0.012*	0.011*
	(0.003)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
PGSI Low		−0.10	−0.12		−0.100	−0.12
		(0.11)	(0.11)		(0.11)	(0.11)
PGSI Moderate		−0.37*	−0.37*		−0.38*	−0.37*
		(0.16)	(0.16)		(0.17)	(0.16)
PGSI Problem		−0.82**	−0.72**		−0.84***	−0.73**
		(0.25)	(0.27)		(0.25)	(0.27)
SBGM Play Freq.	No	Yes	Yes	No	Yes	Yes
Sex	No	No	Yes	No	No	Yes
Age Categories	No	No	Yes	No	No	Yes
Education	No	No	Yes	No	No	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
N	184	184	184	184	184	184
R^2	0.01	0.11	0.17	0.01	0.11	0.17
Adjusted R^2	0.01	0.06	0.09	0.00	0.06	0.08

Note. PGSI Low are scores from 1–4; PGSI Moderate are scores from 5 to 7; and PGSI Problem are scores from 8+. Slot Play Freq. is slot play frequency. Age categories are ten-year bands beginning at '20'. Heteroskedasticity robust standard errors in parentheses.

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

4.1. Limitations & future research

Our study design provides validation where intended, however, it bears emphasizing that there is no definitive clinical or external objective measure by which to evaluate our tests, the GBQ, or gambling-related cognitive distortions more generally. As such, the extent to which our tests can be viewed as useful is dependent on the validity of the tests themselves. Despite our attempts to build those measures deductively rather than subjectively, the absence of the intended results could be a function of a poorly designed test, as opposed to an invalid scale. While the CFA in this study is a more objective measure of construct validity, it also provides less direction in terms of future adaptations of the scale. Also, this study used an internet-based sample from MTurk. Although we followed research best practices, the typical cautions apply.

Future research related to the GBQ or other measures of cognitive distortions should generally be focused in two areas. First, new external tests should be developed to assess the validity of the scales and their component items. Because there is no objective measure of gambling-related cognitive distortions, a rigorous approach to validating the measure is warranted, which should include multiple external validity tests and samples. These could be done using behavioral measures, rather than self-reported ratings. Second, both statistical and experimental methods should be used to refine the GBQ to improve question parsimony and the uniqueness of the subscales. As originally observed by Steenbergh et al. (2002) the GBQ-IoC and the GBQ-LP are closely correlated, with items cross-loaded on both subscales.

Declarations of interest

None

Role of funding sources

Funding for this study was provided by an Australian Research Council Discovery Early Career Research Award [DE1060100459] awarded to Dr. Sally Gainsbury. The ARC had no role in the study design, collection, analysis or interpretation of the data, writing the

manuscript, or the decision to submit the paper for publication.

Contributors

Authors SG and KP designed the study and wrote the protocol, Author GG conducted literature searches. Author KP conducted the statistical analysis and wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

Conflicts of interests

All authors declare that they have no conflicts of interest.

References

Barrault, S., & Varescon, I. (2013). Cognitive distortions, anxiety, and depression among regular and pathological gambling online poker players. *Cyberpsychology, Behavior and Social Networking.* https://doi.org/10.1089/cyber.2012.0150.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin, 107*(2), 238–246. https://doi.org/10.1037/0033-2909.107.2.238.

Blaszczynski, A., & Nower, L. (2002). A pathways model of problem and pathological gambling. *Addiction.*. https://doi.org/10.1046/j.1360-0443.2002.00015.x.

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research, 21*(2), 230–258. https://doi.org/10.1177/0049124192021002005.

Clotfelter, C. T., & Cook, P. J. (1993). Notes: The "Gambler's Fallacy" in Lottery Play. *Management Science.*. https://doi.org/10.1287/mnsc.39.12.1521.

Currie, S. R., Hodgins, D. C., & Casey, D. M. (2013). Validity of the problem gambling severity index interpretive categories. *Journal of Gambling Studies.*. https://doi.org/10.1007/s10899-012-9300-6.

Davis, D., Sundahl, I., & Lesbo, M. (2000). Illusory personal control as a determinant of bet size and type in casino craps games. *Journal of Applied Social Psychology.*. https://doi.org/10.1111/j.1559-1816.2000.tb02518.x.

Dunn, D. S., & Wilson, T. D. (1990). When the stakes are high: A limit to the illusion-of-control effect. *Social Cognition.*. https://doi.org/10.1521/soco.1990.8.3.305.

Ejova, A., Delfabbro, P. H., & Navarro, D. J. (2015). Erroneous gambling-related beliefs as illusions of primary and secondary control: A confirmatory factor analysis. *Journal of Gambling Studies.*. https://doi.org/10.1007/s10899-013-9402-9.

Ferris, J., & Wynne, H. (2001). *The Canadian problem gambling index : User manual.* Ottawa, ON: Canadian Centre on Substance Abusehttps://doi.org/10.1007/s10899-010-9224-y.

Fisher, C. J. (2016). The rise of skill-based gaming regulation. *American Gaming Lawyer,* 28–31 Autumn.

Fortune, E. E., & Goodie, A. S. (2012). Cognitive distortions as a component and treatment focus of pathological gambling: A review. *Psychology of Addictive Behaviors.* https://doi.org/10.1037/a0026422.

Gainsbury, S. M., & Blaszczynski, A. (2017). Virtual reality gambling: Implications for regulation and gambling disorders. *Gaming Law Review, 21*(4), 314–322.

Goodie, A. S., & Fortune, E. E. (2013). Measuring cognitive distortions in pathological gambling: Review and meta-analyses. *Psychology of Addictive Behaviors, 27*(3), 730–743. https://doi.org/10.1037/a0031892.

Goodman, J. K., Cryder, C. E., & Cheema, A. (2013). Data collection in a flat world: The strengths and weaknesses of mechanical Turk samples. *Journal of Behavioral Decision Making.*. https://doi.org/10.1002/bdm.1753.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2010). *Multivariate Data Analysis.* Prentice Hall816. https://doi.org/10.1016/j.ijpharm.2011.02.019.

Hodgins, D. C., Stea, J. N., & Grant, J. E. (2011). Gambling disorders. *The Lancet, 378*(9806), 1874–1884. https://doi.org/10.1016/S0140-6736(10)62185-X.

Holtgraves, T. (2009). Evaluating the problem gambling severity index. *Journal of Gambling Studies.*. https://doi.org/10.1007/s10899-008-9107-7.

Jacobsen, L. H., Knudsen, A. K., Krogh, E., Pallesen, S., & Molde, H. (2007). An overview of cognitive mechanisms in pathological gambling. *Nordic Psychology.*. https://doi.org/10.1027/1901-2276.59.4.347.

Kenny, D.a. (2012). Measuring model fit. *Davidakenny.Net*https://doi.org/10.1186/1748-5908-6-64.

King, D. L., Gainsbury, S. M., Delfabbro, P. H., Hing, N., & Abarbanel, B. L. L. (2015). Distinguishing between gaming and gambling activities in addiction research. *Journal of Behavioral Addictions.* https://doi.org/10.1556/2006.4.2015.045.

Ladouceur, R., & Mayrand, M. (1987). The level of involvement and the timing of betting in roulette. *Journal of Psychology: Interdisciplinary and Applied.*. https://doi.org/10.1080/00223980.1987.9712654.

Langer, E. J. (1975). The illusion of control. *Journal of Personality and Social Psychology.*. https://doi.org/10.1037//0022-3514.32.2.311.

Langer, E. J. (1977). The psychology of chance. *Journal for the Theory of Social Behaviour.* https://doi.org/10.1111/j.1468-5914.1977.tb00384.x.

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods.*. https://doi.org/10.1037/1082-989X.1.2.130.

Marchetti, D., Whelan, J. P., Verrocchio, M. C., Ginley, M. K., Fulcheri, M., Relyea, G. E., & Meyers, A. W. (2016). Psychometric evaluation of the Italian translation of the Gamblers' Beliefs Questionnaire. *International Gambling Studies, 16*(1), 17–30.

Marjanovic, Z., Struthers, C. W., Cribbie, R., & Greenglass, E. R. (2014). The conscientious responders scale: A new tool for discriminating between conscientious and random responders. *SAGE Open.* https://doi.org/10.1177/2158244014545964.

Mattson, R. E., MacKillop, J., Castelda, B. A., Anderson, E. J., & Donovick, P. J. (2008). The factor structure of gambling-related cognitions in an undergraduate university sample. *Journal of Psychopathology and Behavioral Assessment.* https://doi.org/10.1007/s10862-007-9063-z.

Oei, T. P. S., & Gordon, L. M. (2008). Psychosocial factors related to gambling abstinence and relapse in members of gamblers anonymous. *Journal of Gambling Studies.*. https://doi.org/10.1007/s10899-007-9071-7.

Pilatti, A., Cupani, M., Tuzinkievich, F., & Winfree, W. (2016). Confirmatory factor analysis of the Spanish version of the Gamblers' Beliefs Questionnaire in a sample of Argentinean gamblers. *Addictive Behaviors Reports.*. https://doi.org/10.1016/j.abrep.2016.09.001.

Preacher, K. J., & Coffman, D. L. (2006). *Computing power and minimum sample size for RMSEA*.

Raylu, N., & Oei, T. P. S. (2004). The Gambling Related Cognitions Scale (GRCS): Development, confirmatory factor validation and psychometric properties. *Addiction.*. https://doi.org/10.1111/j.1360-0443.2004.00753.x.

Satorra, A., & Saris, W. E. (1985). Power of the likelihood ratio test in covariance structure analysis. *Psychometrika.*. https://doi.org/10.1007/BF02294150.

Sharpe, L., & Tarrier, N. (1993). Towards a cognitive-behavioural theory of problem gambling. *British Journal of Psychiatry.*. https://doi.org/10.1192/bjp.162.3.407.

Smith, D., Woodman, R., Drummond, A., & Battersby, M. (2016). Exploring the measurement structure of the Gambling Related Cognitions Scale (GRCS) in treatment-seekers: A Bayesian structural equation modelling approach. *Psychiatry Research.* https://doi.org/10.1016/j.psychres.2016.02.002.

StataCorp (2017). *Stata structural equation modeling Reference Manual Release 15.* College Station, Texas: Stata Press.

Steenbergh, T. A., Meyers, A. W., May, R. K., & Whelan, J. P. (2002). Development and validation of the Gamblers' Beliefs Questionnaire. *Psychology of Addictive Behaviors, 16*(2), 143–149. https://doi.org/10.1037/0893-164X.16.2.143.

Sundali, J., & Croson, R. (2006). Biases in casino betting : The hot hand and the gambler ' s fallacy. *Judgment and Decision Making.* retrieved from: http://journal.sjdm.org/jdm06001.pdf.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education.*. https://doi.org/10.5116/ijme.4dfb.8dfd.

Toneatto, T., Blitz-Miller, T., Calderwood, K., Dragonetti, R., & Tsanos, A. (1997). Cognitive distortions in heavy gambling. *Journal of Gambling Studies.*. https://doi.org/10.1023/A:1024983300428.

Walker, M. B. (1992). *The psychology of gambling.* Elmsford, NY, USA: Pergamon Press.

Winfree, W. R., Ginley, M. K., Whelan, J. P., & Meyers, A. W. (2015). Psychometric evaluation of the Gamblers' Beliefs Questionnaire with treatment-seeking disordered gamblers. *Addictive Behaviors, 43*, 97–102. https://doi.org/10.1016/j.addbeh.2014.12.016.

Winfree, W. R., Meyers, A. W., & Whelan, J. P. (2013). Validation of a Spanish translation of the Gamblers' Beliefs Questionnaire. *Psychology of Addictive Behaviors.* https://doi.org/10.1037/a0030824.

Wong, S. S. K., & Tsang, S. K. M. (2012). Validation of the Chinese version of the Gamblers' Belief Questionnaire (GBQ-C). *Journal of Gambling Studies.*. https://doi.org/10.1007/s10899-011-9286-5.

Xian, H., Shah, K. R., Phillips, S. M., Scherrer, J. F., Volberg, R., & Eisen, S. A. (2008). Association of cognitive distortions with problem and pathological gambling in adult male twins. *Psychiatry Research.* https://doi.org/10.1016/j.psychres.2007.08.007.

Xu, J., & Harvey, N. (2014). Carry on winning: The gamblers' fallacy creates hot hand effects in online gambling. *Cognition.*. https://doi.org/10.1016/j.cognition.2014.01.002.