Validating a Home Numeracy Questionnaire in Ecuador Using Factor Analysis

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ARTICLE INFO	ABSTRACT
	The home numeracy questionnaire (HNQ) developed by LeFevre et al. (2009) is a self-report instrument to assess the home numeracy of young children. In this questionnaire, young children's parents have to indicate how often their child participates both in direct (e.g., counting down: 10, 9, 8, …) and indirect numeracy activities (e.g., playing board games with die or spinner). Based on a principal component analysis, LeFevre and colleagues found a four factor structure of the HNQ. Using a sample of 176 Ecuadorian parents, we investigated the validity and reliability of the HNQ in a developing country. A confirmatory factor analysis indicated that, with minor changes to the model, the same four factor model could be found as by LeFevre et al. (2009). This study not only confirmed the validity and reliability of the HNQ, but also showed its usefulness for investigating young children's home numeracy beyond developed countries.

INTRODUCTION

Before children enter school, they have already developed some initial numerical competencies (Clements & Sarama, 2007; Torbeyns, Gilmore, & Verschaffel, 2015), which are characterized by heterogeneity (Anders, Grosse, Roßbach, Ebert, & Weinert, 2012). This heterogeneity is problematic, since children's initial numerical competencies are important predictors for their later mathematics achievement (e.g., De Smedt, Verschaffel, & Ghesquière, 2009; Geary & vanMarle, 2016). A similar heterogeneity has been found in children's early reading achievement. Moreover, early literacy research shows that young children's home literacy before entering school is related with their early and later reading competencies (e.g., Sénéchal & LeFevre, 2002). Importantly, stronger relations have been found between indirect home activities (i.e., activities where the development of reading is more incidental, such as storybook reading) and reading-related outcomes than to direct home activities (i.e., activities with the explicit aim to develop reading skills, such as teaching about word reading) (Sénéchal & LeFevre, 2002).

Taking these home literacy studies as point of departure, the same assumption was made about the pivotal role of young children's home numeracy for their current and later numerical competencies. However, until the first years of the past decade this assumption was almost exclusively shown in a few longitudinal studies indicating the predictive role of young children's early numerical skills for their mathematical achievement in elementary school, without explicitly investigating their home numeracy (e.g., Aunola, Leskinen, Lerkkanen, & Nurmi, 2004). Moreover, these longitudinal studies focused on direct numeracy activities, i.e., activities with the explicit aim to develop quantitative skills (e.g., counting to 10). Indirect numeracy activities, without explicit focus on developing quantitative skills and thus with more incidental numeracy development (e.g., playing board games having a numerical dimension), were not included.

In 2009, LeFevre and colleagues developed a home numeracy questionnaire (HNQ) to address these shortcomings. In that questionnaire parents have to indicate how often their child participates both in direct and indirect numeracy activities. Based on items used in previous research (e.g., Anderson, 1998; Huntsinger, Jose, Larson, Balsink Krieg, & Shaligram, 2000) and on observations of activities taking place in Canadian households, a total of 17 items were selected to measure home numeracy. Using a 5-point scale, the parents of 146 young children indicated the frequency with which their child participated on the 17

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activities (for an overview of the 17 items, see Table 1). The HNQ was characterized by a high reliability (for more details, see LeFevre et al., 2009). To investigate the underlying structure of the HNQ, LeFevre and colleagues (2009) performed a principal components analysis with varimax rotation. Four factors were extracted: number skills, number books, games, and applications. In line with their expectations, the factors reflected the distinction made in the questionnaire between items measuring the direct (number skills and number books) versus indirect (games and applications) numeracy activities.

Departing from the study of LeFevre and colleagues (2009), an increasing number of researchers developed similar home numeracy questionnaires (e.g., Segers, Kleemans, & Verhoeven, 2015), also characterized by a distinction between direct and indirect numeracy activities (e.g. Skwarchuk, Savinski, & LeFevre, 2014). However, these questionnaires were constructed and validated in developed countries, leaving their usability in developing countries an open question.

In the present study, we examine the psychometric properties of the HNQ (LeFevre et al., 2009) in a developing country, namely Ecuador, to check whether the HNQ can be used to investigate kindergartners' home numeracy beyond developed countries. Because there are currently no instruments available in Ecuador for measuring young children's home numeracy, this study has practical relevance too. We investigated the validity and reliability of the HNQ, by examining whether the same four factor structure could also be found in a developing country. As a developing country (United Nations, 2016), Ecuador is strongly different in its general and educational context compared to Canada, as, for instance, indicated by Ecuadorian children's problematically low level of mathematics performance compared to the level of their peers in developed countries (Bojorque, Torbeyns, Hannula-Sormunen, Van Nijlen, & Verschaffel, 2017; UNESCO, 2008). This makes Ecuador a very suitable country to validate a test instrument constructed in a developed country.

METHOD

The current study fits into a larger research project investigating the role of child and context characteristics in Ecuadorian kindergartners' early mathematical development (see Bojorque, Torbeyns, Van Hoof, Van Nijlen, & Verschaffel, 2017 for more details). To have a good representation of the different school contexts in Ecuador, we included schools from the three major school types: public urban (3 schools, 59 kindergartners), public rural (3 schools, 58 kindergartners), and private (3 schools, 59 kindergartners). In total, parents of 176 kindergartners (87 boys; Mage = 5 years 2 months [SD = 3.7 months] participated in the study. Concerning ethnicity, all kindergartners were mestizos.

Data were collected according to the ethical guidelines of the University of Cuenca and the KU Leuven. The HNQ was translated into Spanish by the second author of this study.

RESULTS AND DISCUSSION

Data were analyzed by a confirmatory factor analysis via the AMOS statistical package on the 17 questions of the HNQ of LeFevre et al. (2009). There were no missing data. As shown in Table 1, the means on the different items in our sample were in the most cases slightly higher compared to the means in the study of LeFevre and colleagues (2009).

By means of SPSS 24, we evaluated the assumptions of normality, multicollinearity, and linearity, which we met. Moreover, using Mahalanobis distance, we observed no univariate or multivariate outliers. We chose a maximum likelihood over other estimation methods since our data were normally distributed. Based on the results of LeFevre and colleagues (2009), we hypothesized a four factor model.

A confirmatory factor analysis using this model resulted in a significant χ^2 statistic, indicating an insufficient fit between the hypothesized model and the observed data (χ^2 (113, n = 176) = 180.72, p < .001). This lack of fit was confirmed by a RMSEA value of .06 that exceeded the cut-off point of 0.05 for accepting the model fit. Also the AIC (260.72) and BIC (791.08) values showed room for improvement of the model. Post-hoc modifications were needed to find a model that would fit the data.

In a first step, modification indices showed that excluding the item "Connect-the-dot activities" and the item "Playing card games" would improve the model fit. This was reflected in the acceptable RMSEA value of .04 and lower AIC (182.40) and BIC values (296.54). However, the χ^2 statistic was still significant (χ^2 (84, n = 176) = 110.40, p = .03), suggesting that it was possible to improve the model fit further. Based on the modification indices, it was clear that the item "Counted down (10, 9, 8, 7, …)" did not fit the model well. After excluding this item, the model was characterized by a non-significant χ^2-value (χ^2 (71, n = 176) = 82.61; p = .16), suggesting an acceptable fit of the model. This was confirmed by the RMSEA value of .03 and the lower AIC (150.61) and BIC values (258.40).

Table1. Overview of the four factor structure of the home numeracy questionnaire

Description	Squared multiple correlations	Mean (SD)	Mean (SD) LeFevre
Number skills			
Counting objects	.55	3.23 (1.13)	2.8 (1.2)
Sort things by size, color or shape	.52	2.65 (1.32)	1.8 (1.4)
Counted down (10, 9, 8, 7, …)*		1.87 (1.44)	1.8 (1.2)
Printing numbers	.38	3.16 (1.09)	2.7 (1.2)
Identifying names of written numbers	.26	2.54 (1.32)	2.1 (1.4)
Number books			
"Connect-the-dot" activities*		1.82 (1.51)	1.9 (1.2)
Using number activity books	.53	2.35 (1.36)	1.7 (1.3)
Reading number storybooks	.53	1.73 (1.45)	1.7 (1.3)
Games			
Playing card games*		1.94 (1.50)	2.1(1.1)
Making collections	.11	2.08 (1.49)	1.8 (1.2)
Playing board games with die or spinner	.28	1.54 (1.44)	2.0 (1.1)
Being timed	.24	2.01 (1.51)	1.7 (1.4)
Applications			
Having your child wear a watch	.35	1.23 (1.32)	1.2 (1.4)
Measuring ingredients when cooking	.37	1.36 (1.36)	1.8 (1.1)
Using calendars and dates	.52	1.12 (1.22)	3.0 (1.1)
Talking about money when shopping (e.g., "which costs more?")	.37	2.11 (1.53)	2.4 (1.1)
Playing with calculators	.31	1.57 (1.43)	1.4 (1.2)

Note. The items with an asterisk are the three items with a bad fit in the model. The question for each item was: In the past month, how often did you and your child engage in the following activities? Circle 0 if the activity did not occur, 1 if it occurred less than once a week, but a few times a month (1-3 times), 2 if it occurred about once a week, 3 if it occurred a few times a week (2-4 times), 4 if it occurred almost daily, and NA if the activity is not applicable to your child

The total reliability of the HNQ (without the three problematic items) was high (Cronbach's alpha = .87). Additionally, the squared multiple correlations are displayed in Table 1. These correlations describe the total amount of variance in every item explained by the factor.

DISCUSSION

This study revealed that the HNQ as developed and used by LeFevre and colleagues (2009) is a valid and reliable instrument to assess young children's home numeracy in a developing country, namely Ecuador. A confirmatory factor analysis indicated that, with minor changes to the model, LeFevre et al.'s four factor model was replicated. This means that the HNQ, constructed in a developed country, also shows sufficient psychometric qualities in a developing country and can be used to assess young children's home numeracy beyond developed countries in a reliable and valid way. This is important, given the lack of questionnaires measuring the home numeracy of young children in developing countries.

These findings have important implications for future studies, since the HNQ can be used to yield a better view on young children's home numeracy in developing countries. Moreover, previous findings coming from developed countries can be complemented by investigating whether the pivotal role of children's home numeracy for their current and later mathematics achievement also applies in young children coming from developing countries. These studies can provide the needed insights for educational practices to develop interventions in children's home environment aimed at increasing children's early numerical abilities in developing countries.

It should be noted that we only addressed the construct validity of the HNQ. As stated by van de Vijver and Tanzer (2004), the cross-cultural comparison of results obtained through a questionnaire, can have a different meaning compared to an intracultural comparison. This might also have played a role in the present study. The −counterintuitive − slightly higher scores in the Ecuadorian sample compared to the Canadian sample can have several explanations, such as Ecuadorian parents' greater subjectivity to social desirability, Ecuadorian parents' greater tendency to use the extremes of a given scale (e.g., van de Vijver & Tanzer, 2004), or subtle linguistic differences in the Spanish translation of the HNQ. Therefore, to address this pitfall in future studies, questionnaires such as the HNQ should be triangulated with other methodologies for investigating young children's home numeracy, such as in-depth interviews or home observations (e.g., Susperreguy & Davis-Kean, 2016).

CONCLUSION

The present study showed that the HNQ, constructed in a developed country, has been proven valid and reliable. Therefore, the questionnaire can be used to shed light on young children's home numeracy in developing countries too. This is an important finding, given that, for the moment, there is a lack of reliable and valid test instruments testing children's home numeracy in those countries. For example, the HNQ can be used in future intervention studies wherein the analysis of children's home numeracy is taken as a starting point for intervention aimed at enriching children's home environments (Ökten, 2016), to better prepare children for early mathematics education at school (see for example Verschaffel, Torbeyns, & De Smedt, 2017). This is very important given that the level of education and skill children have has a large influence on employment rate (Hindun, 2019).

We have to acknowledge that in the present study, we only investigated the construct validity of the HNQ investigated and not the ecological and cross-cultural validity. Therefore, future studies should, firstly, investigate the ecological validity by shedding light on the question to which degree the answers to the HNQ predict actual behaviors in real-world settings. Secondly, given that cultural differences may influence how participants interpret and answer a questionnaire, future studies should also investigate the cross-cultural validity of the HNQ. For example, Küçükdeveci, Sahin, Ataman, Griffiths, & Tennant (2004) illustrated how cross-cultural validity can be assessed through the use of differential item functioning.

Such studies on the ecological and cross-cultural validity of the instrument, complemented with qualitative methodologies such as in-depth interviews or observations (e.g., Susperreguy & Davis-Kean, 2016), are an important building block for addressing a timely topic within early mathematics education, namely the contribution of home numeracy activities and specific mathematical competencies (such as basic number processing and calculation skills). By focusing on specific mathematical abilities instead of a general score of mathematics achievement, studies can give an explanation for the contradictory findings in the literature on the association between children's home numeracy and mathematical abilities (Mutaf, Sasanguie, De Smedt, & Reynvoet, 2018). Moreover, future research should include control variables that have been shown to play a role in the relation between home numeracy and mathematics achievement, such as children's age (see for example Thompson, Napoli, & Purpura, 2017).

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