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Neonatal Behavioral Assessment Scale (NBAS): Confirmatory factor analysis of the six behavioral clusters

Miguel Barbosa[a,b,*], João Moreira[a], Edward Tronick[c,d], Marjorie Beeghly[e], Marina Fuertes[f,g]

[a] Universidade de Lisboa, Faculdade de Psicologia, Lisboa, Portugal
[b] Universidade de Lisboa, Faculdade de Medicina, Lisboa, Portugal
[c] University of Massachusetts Boston, Department of Psychology, Developmental Brain Sciences Program, USA
[d] Harvard Medical School, Department of Newborn Medicine, USA
[e] Wayne State University, Detroit, MI, USA
[f] Instituto Politécnico de Lisboa, Escola Superior de Educação, Portugal
[g] Universidade do Porto, Centro de Psicologia, Faculdade de Psicologia e de Ciências da Educação, Portugal

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ABSTRACT

The Neonatal Behavioral Assessment Scale (NBAS) is a widely used in the neurobehavioral assessment of neonates in clinical practice and research. Lester's data reduction system for the NBAS items is the most often used in research, but the few factor analytic studies carried out with it leave gaps in its validation. The current study aimed to test and compare (a) the factorial structure of the Lester's data reduction system for the NBAS and (b) an alternative data reduction system, slightly modified from Lester's system. The NBAS was administered to 196 healthy Portuguese full-term infants (51% male) in the first 72 h of life (M = 43.63 h). Construct validity of the data reduction systems was tested through confirmatory factor analysis (CFA). Lester's original system was compared to three alternative models, two of which included a revision of the scoring rules for three items and the exclusion of five items. The CFA generally supported the six-factor structure. However, fit indices for Lester's original model were only fair. An alternative, revised model with a second-order factor – Self-Organizing System – demonstrated a better fit. The results provide evidence to support a modified form of Lester's six behavioral clusters as a data reduction model for the NBAS items.

1. Introduction

Neonatal assessment has largely contributed to current view that infants are competent organisms actively involved in shaping their extrauterine environments. It has also expanded our knowledge about individual differences in newborn behavior at birth and how best to support infants' further development. The Neonatal Behavioral Assessment Scale (NBAS) has significantly contributed to this field for more than four decades by assessing newborns' behavioral repertoire and neurological status in research and clinical settings [1–5]. The NBAS has been used to address a variety of issues, including comparing typical and at risk infants, identifying factors that alter newborns' neurobehavioral profiles (e.g., gender and culture), and using the NBAS in intervention (e.g., [6–12]).

Considering the wide use of the NBAS, a valid data reduction system is critical to its validity. Although some studies employ item-by-item comparisons (e.g., [13,14]), most evaluate factors or clusters derived using different methods, typically a priori clustering or factor analysis. Lester's data reduction system for the NBAS items is the most often used in research, but the few factor analytic studies carried out with it leave a number of gaps in its validation. The current study addresses these gaps by testing (a) the factorial structure of the Lester's data reduction system for the NBAS and (b) an alternative data reduction system, slightly modified from Lester's system.

1.1. Exploratory factor analysis in NBAS studies

The number of factors extracted in exploratory factor analysis (EFA) studies of the NBAS varies between 3 and 11 (e.g., [15–22]). Importantly there are variations in the items that compose each factor across studies, as well as the specific names used to identify them. In all the EFA studies, Animate Visual and Alertness items load on the social-interactive factor. Other single items are found consistently in different factors: Rapidity of Build-Up in the state organization factors; Self-

* Corresponding author at: Faculdade de Medicina da Universidade de Lisboa, Av. Prof. Egas Moniz, 1649-028 Lisboa, Portugal.
E-mail addresses: mbarbosa@medicina.ulisboa.pt (M. Barbosa), joao.moreira@campus.ul.pt (J. Moreira), ed.Tronick@umb.edu (E. Tronick), beeghly@wayne.edu (M. Beeghly), marinaf@eselx.ipl.pt (M. Fuertes).

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Quieting in the regulation of state factor; General Tone in the motor factor; and Response Decrement to Light, Rattle, and Bell in the habituation factor. However, some items fail to load on any of the Lester et al. [10] factors For example, in several studies, Motor Maturity and Defensive Movements items do not load consistently on the motor factor (e.g., [23,24]), nor Cuddliness in regulation of state factor (e.g., [18]).

A number of methodological issues may contribute to variations in the inter-correlations among the items and explain variations in the factor analytic results across studies. These issues include the use of small samples, diverse populations (healthy or at-risk), the use (vs. non-use) of item recoding as described above, the exclusion of some of the standard items (e.g., habituation or social-interactive items), the inclusion of additional items, the use of differing thresholds to consider whether loadings are meaningful, different methods of factor extraction and rotation, different criteria for determining the number of factors, and different methods for dealing with missing data.

1.2. Confirmatory factor analysis in NBAS studies

To the best of our knowledge only two studies have examined the NBAS using confirmatory factor analysis (CFA), a multivariate statistical procedure recommended for the assessment of construct validity [25]. Azuma, Malee, Kavanagh, and Deddish [26] tested four different models on a sample of 166 preterm infants and failed to find a good fit for any of the models. A two-factor model including orientation and arousal dimensions had the highest adjusted goodness-of-fit index (AGFI = 0.78). The authors hypothesize that the lack of confirmation of Lester's behavioral clusters may be related to the peculiarities of at-risk preterm infants, and recommend the use of CFA in a typical full-term infant sample. McCollam, Embretson, Mitchell, and Horowitz [27] assessed four variations of Lester's behavioral clusters in a sample of 160 healthy full-term infants. The best-adjusted model resulted from the inclusion of an additional General Adaptiveness factor, on which items were allowed to load, in addition to Lester's six first-order clusters. Although the results indicate that Lester's behavioral clusters are a good baseline for scoring the 27-behavioral-item set, McCollam et al. [27] suggest that future studies should consider modifications to the system. The study by McCollam et al. [27] shows that some Lester factors were correlated, some of the items appear more general than specific to a given cluster, and some variables consistently fail to load on their Lester cluster. These results suggests that and a revised Lester correlated factors model seems to be the most viable [27].

1.3. Exploratory proposal for modifications of some items in the Lester's data reduction system

Introducing modifications into the reduction data system may prove worthwhile. It is our views that the way some items are scored may be influencing the factorial validity of the NBAS. Based on the extant literature and our own studies and experience with the NBAS, we propose an alternative system, which includes slight modifications of the scoring criteria of three items and the exclusion of five items typically used in the Lester's data reduction system.

The first proposed change is not to consider any infant tremors that may occur during the social-interactive items, when calculating the final score for the Tremulousness item. In prior work, we observed significant differences in the Tremulousness item and in the Autonomic Stability cluster between a group of infants who did the social-interactive items while swaddled and their non-swaddled counterparts: the former showed higher scores [28]. Removing Tremulousness from the scoring of the social-interactive items from the analysis would eliminate this confound.

The second proposed change is to modify the guidelines slightly for scoring the Lability of State item (e.g., the best score should correspond to 1–2 state changes, but only when the predominant state is a state 4, i.e., alert). The full nine points of the scale should continue to be used but reversed (see Table 1). We believe this change will increase the discriminatory power of this item, compared with the current recommended procedure [3,4].

Table 1
Original and revised scoring of the Lability of State item.

	Original	Revised
1	1–2 state changes observed over the course of the examination	17 or more state changes, or if the exam is interrupted because infant is distressed or drowsy
2	3–4 state changes	15–16 state changes
3	5–6 state changes	13–14 state changes
4	7–8 state changes	11–12 state changes
5	9–10 state changes	9–10 state changes
6	11–12 state changes	7–8 state changes
7	13–14 state changes	5–6 state changes
8	15–16 state changes	3–4 state changes
9	17 or more state changes	1–2 state changes (if state 4 is predominant)
	Recode: 9 = 1; 7/8 = 2; 5/6 = 3; 3/4 = 4; 1/2 = 5	No recoding

Third, we propose making a minimal change in the recoding of the Peak of Excitement item, such that 7/5 = 4 and 6/4 = 5, instead of the original scoring criteria of 7/4 = 4, and 5/6 = 5. Our rationale is that an infant with score of 4 (“infant is predominantly in State 4 [alert], but may reach State 5 [considerable motor activity] or 6 [crying] briefly”) displays a higher capacity to regulate her/his states and maintain a predominantly alert state, compared to an infant with a score of 5 (“infant is predominantly in State 5, but reaches State 6 [for 15 seconds] once or twice during the examination”).

The fourth proposed change is to exclude five items from the analysis, because some consistently fail to load on the clusters specified by Lester (i.e., Cuddliness, Motor Maturity, and Defensive Movements) or are altered by variations in nursery routines (i.e., Response Decrement to Tactile Stimulation of the foot) and the examiner's strategy of administration (i.e., Rapidity of Build-Up, once the NBAS has no fixed sequence of administration).

1.4. The current study

The changes we propose in our modified scoring system could have important implications for the factorial validity of the NBAS and its use in future research. Therefore, the purpose of the current study was to (a) test the factorial structure of the original Lester's six behavioral clusters system, and (b) compare it to an alternative scoring procedure, involving minor modifications of Lester's system as described above. Given that CFA is the most appropriate statistical procedure to test construct validity, we employed it test and compare both systems.

2. Methods

2.1. Participants

A total of 196 healthy full-term infants (51% male), whose gestational age ranged between 37 and 42 weeks (M = 39.59, SD = 1.17), with a birth weight above 2500 g (M = 3321, SD = 413.22; range: 2500–4350) and Apgar scores of 8 or more (M = 9.10 at 1-min, SD = 0.70; M = 9.96 at 5-min, SD = 0.20) were included in the study. Their mothers had received routine prenatal care and had no history of chronic diseases, mental health disorders, or prenatal alcohol/drugs abuse; 97.5% received epidural analgesia during labor. Mothers' mean age was 30.76 years (SD = 4.77; range: 20–40), their mean years of completed education was 14 years (SD = 3.76; range: 6–23), 89% self-reported as Portuguese in ethnicity, and 60% were primiparous. The NBAS was administered in the first 72 h of life (M = 43.63 h,

$SD = 18.61$).

2.2. Measures

2.2.1. Neonatal Behavioral Assessment Scale, 4th edition

The NBAS [4] is a neurobehavioral assessment tool designed to describe newborn competencies and to identify individual differences in neonatal behavioral development and adaptation to the extrauterine environment. The newborn's behavioral repertoire and neurological status are captured by 27 behavioral items, each scored on a nine-point scale, and 18 reflex items, each scored on a four-point scale. The frequency of the infants´ smiles during the exam is also scored, and qualitative differences in infants' neurobehavior are rated using seven supplementary observational items (scored on a nine-point scale), in order to describe the behavior of high-risk infants more effectively. The scale items cover the different domains or systems of neurobehavioral functioning: autonomic/physiological regulation, motor organization, state organization and regulation, and attention/social interaction. The exam takes approximately 30 min to administer and is appropriate for infants ranging in age from birth to the end of the second month of life.

2.3. Procedures

The NBAS was administered to all infants under standardized conditions within 72 h of birth and prior to discharge from the hospital. This time period was chosen so as minimize the time of exposure to influences of parenting and to profit from the standardized environmental conditions of the hospital nursery. The NBAS exams were performed and scored by a certified examiner, approximately at midpoint between feedings. All examinations were videotaped. The examinations were scored immediately after administration, according to the criteria specified in the fourth edition of the NBAS manual [4] with the support of video recordings. High interobserver reliability (i.e., achieving agreements > 0.90) was assured by requiring that 20% of the NBAS exams be independently scored by two certified examiners.

We followed most psychometric studies in excluding the reflexes cluster and smiles from analyses. Concerning the recoding scheme, the items with midrange optimal scores were recoded as recommended by Brazelton & Nugent [3,4] and Lester et al. [10].

The Ethics Committee of the Lisbon Academic Medical Centre approved the study. All enrolled parents completed a written informed consent.

2.4. Statistical analyses

CFAs were carried out using the AMOS software (v. 22, SPSS, Chicago, IL) and the maximum likelihood estimation method. The original Lester's six behavioral clusters model and three alternative models were comparatively tested (Table 2). Model 1 (original Lester's six behavioral clusters system) and Model 2 were tested with the original scoring of 27 behavioral NBAS items. Models 3 and 4 were tested with the revised scoring, including the revision of the scoring criteria of three items (i.e., Tremulousness, Lability of State, and Peak of Excitement) and the exclusion of five items (i.e., Response Decrement to Tactile Stimulation of the foot, Rapidity of Build-Up, Motor Maturity, Defensive Movement, and Cuddliness). In Models 1 and 3, the six first-order factors based on the Lester's system were allowed to correlate freely, whereas in Model 2 and 4 the correlations among factors were explained by a second-order latent factor we named Self-Organizing System.

To evaluate overall model fit, several indices were used with recommended cut-points: chi-square to degrees of freedom ratio (χ^2/df values between 1 and 2 indicate a good model fit [29]), Comparative Fit Index and Tucker Lewis Index (CFI and TLI ≥ 0.90 indicate a good model fit; [30]), and Root-Mean-Square Error of Approximation (RMSEA ≤ 0.05 indicate a very good fit; > 0.05 and ≤ 0.08 acceptable; [31]).

Modifications to the original models were introduced to obtain a better fit to the data, based on Modification Indices (MIs) suggested by the software and accepted when theoretically justified. A chi-square test was used to compare original and modified models and to confirm the superiority of the latter [32]. We also used the Modified Expected Cross-Validation Index (MECVI) and Akaike Information Criterion (AIC) fit index to compare non-nested models, with lower values suggesting better fit. The full correlation matrix, together with means and standard deviations for the 30 (original and revised) items is available upon request from the first author.

3. Results

CFA was carried out to test the fit of the original Lester's six behavioral clusters and three alternative models (Table 2). The results for Model 1a indicated that some fit indices (e.g., CFI and TLI) failed to meet the criteria for adequate model fit and yielded anomalous results (e.g., items were not significantly correlated with their respective factor or inter-factor correlations were higher than 1), even after the introduction of the modifications suggested by the software (Model 1b).

With the exception of the Habituation and Motor system factors, Lester's factors were moderately or highly intercorrelated. Therefore, and following McCollam et al.'s [27] idea of a general factor, we tested a model with a second-order factor we named Self-Organizing System.

Model 2a included this second-order factor with the original item scoring. Results yielded mixed results concerning fit indices, with CFI and TLI indicating a poor model fit. Even after accepting the modifications suggested by MIs (Model 2b), CFI and TLI continued to fail to meet the minimum criteria for adequate model fit and some anomalous results remained, as was observed for Model 1b.

Model 3a included the revised NBAS items but no second-order factor. CFA results revealed inconsistent fit indices, with the CFI and TLI indicating a poor model fit. With the modifications suggested by MIs (i.e., correlations between errors of Animate Visual and Animate Visual/Auditory; Animate Visual/Auditory and Animate Auditory; and Self-Quieting and Hand-to-Mouth items), the model fit was significantly improved (Model 3b). All items were significantly correlated with the respective factors.

In the final model (4a), the revised versions of some NBAS items and the Self-Organizing System factor, with loadings from the six Lester factors, were included. Indices suggested that the model had a marginal fit, with CFI and TLI below 0.90. However, adding the modifications suggested by MIs (i.e., those indicated above for Model 3b plus correlations between the errors of the General Tone and Pull-to-Sit; Startles and Lability of Skin Color; and Peak of Excitement and State Regulation items), a significant improvement in the quality of fit indices was obtained. Thus, model (4b) provided the best fit of all. Compared to Model 3, it is also conceptually clearer and more parsimonious. It should be noted, however, that the modifications introduced in Model 3b and 4b did not substantially change the findings from the original Lester's model. The standardized parameter estimates for Model 4 is shown in Fig. 1. As evident in the figure, all NBAS factors showed high positive correlations with the Self-Organizing System second-order factor.

4. Discussion

The goal of the current study was to assess the factorial validity of the original Lester's six behavioral clusters model for scoring and data reduction in the NBAS, and to compare it to three alternative models. To accomplish this, we used CFA in a sample of Portuguese healthy full-term infants in the first 72 h of life. Results in our final model (Model 4b) represent an improvement upon Lester's original clusters system, while retaining the essence of Lester's original contribution. In addition to the six behavioral clusters proposed by Lester et al. [10], our model includes a Self-Organizing System factor, providing some initial support

Table 2
Summary of CFA model fit indices.

Model	χ^2	*df*	CMIN/DF	CFI	TLI	PCFI	RMSEA	AIC	MECVI
1a	544,17 $p < .001$	309	1.76	0.83	0.79	0.68	0.06	736.17	3.92
1b	491,17 $p < .001$	305	1.61	0.86	0.83	0.70	0.06	691.17	3.70
2a	584,28 $p < .001$	318	1.84	0.80	0.77	0.68	0.07	758.28	4.02
2b	522,36 $p < .001$	312	1.67	0.84	0.81	0.70	0.06	708.36	3.77
3a	343.94 $p < .001$	194	1.77	0.89	0.85	0.68	0.06	505.94	2.69
3b	298.40 $p < .001$	191	1.56	0.92	0.89	0.69	0.05	466.40	2.49
4a	373.05 $p < .001$	203	1.84	0.87	0.84	0.70	0.07	517.05	2.74
4b	290.25 $p < .001$	197	1.47	0.93	0.91	0.72	0.05	446.25	2.38

Note: a = original model; b = modified model (after entering the MIs); χ^2 = chi square goodness of fit statistic; *df* = degrees of freedom; CMIN/DF = chi-square to degrees of freedom ratio; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; AIC = Akaike Information Criterion; MECVI = Modified Expected Cross-Validation Index.

for deriving a global score (as well as cluster scores) in scoring the NBAS. Another contribution is the successful testing of several NBAS item revisions. These two changes were utilized in Model 4b, which produced the best fit indices to the observed data, much better than those obtained in the two previous CFA studies of the NBAS [26,27]. Our results suggest that Model 4b is the most accurate description, among those tested, of the behavioral organization of newborns in our sample.

Previous factor analytic studies point to the need to improve the psychometric properties of the NBAS [26], including modifying the configuration of Lester's clusters [27]. Based on our clinical and research experience with the NBAS, we addressed this challenge by proposing some minor changes that were reflected in Models 3b and 4b. In addition to the modifications described in the introduction (i.e.,

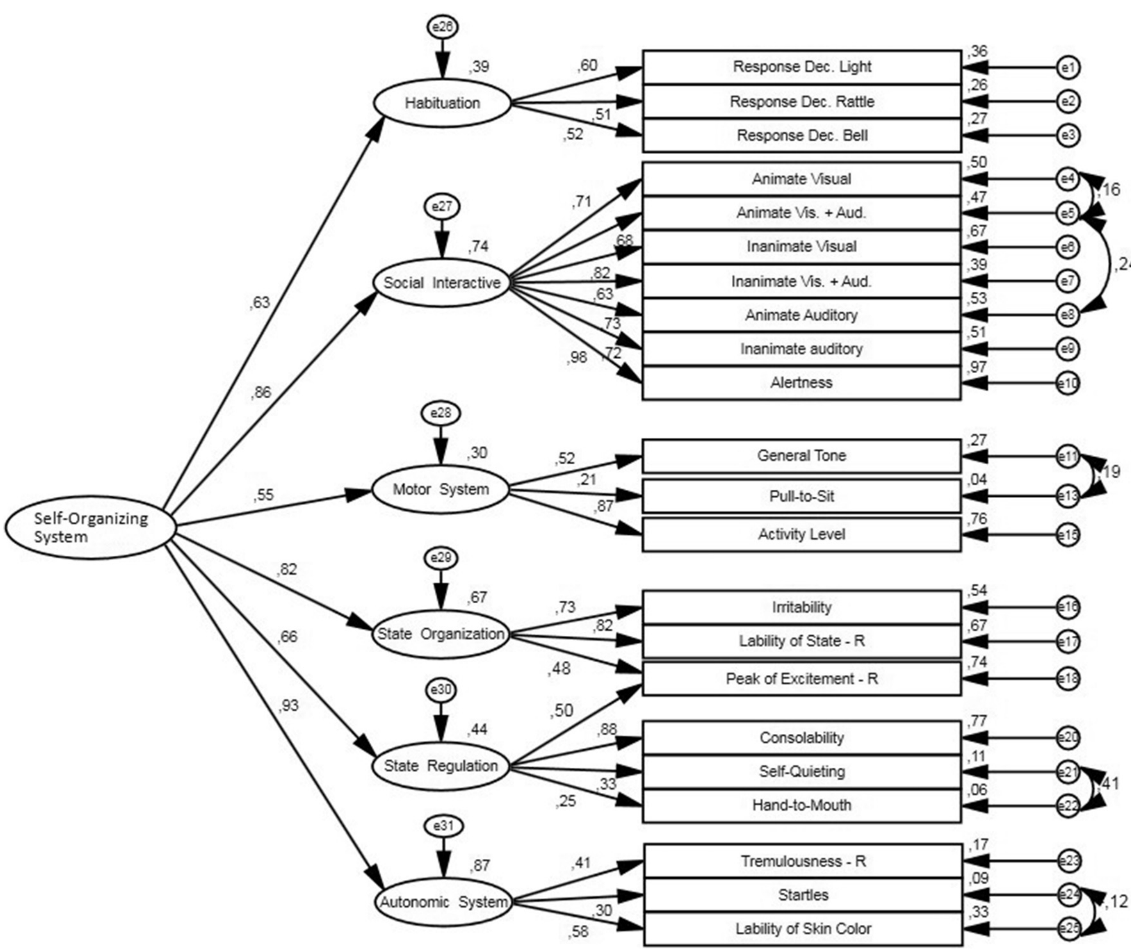

Fig. 1. Path diagram for Model 4b, with standardized parameter values.

exclusion of Response Decrement for Foot, Rapidity of Build-Up, Cuddliness, Motor Maturity, and Defensive Movements items; and our revision of scoring criteria for Peak of Excitement, Lability of States, and Tremulousness items), we allowed the Peak of Excitement item to load on both the state regulation factor and the state organization factor. Although this additional loading was not initially considered, we justified this using the criteria for scoring Peak of Excitement outlined in the NBAS manual. Note that the first five levels of scoring focus only on the predominant state of the infant (e.g., score 3: "infant is predominantly in state 3 [drowsiness] or lower but may reach state 4 [alert] briefly"). However, from level 6 to 9, the criteria also include the dimensions of self-quieting (score 6: "infant reaches State 6 more than twice during the examination, but returns to lower states spontaneously, at least twice") and consolability (score 7–9, e.g., score 7: "infant reaches state 6 more than twice, but with consoling is easily brought back to lower states"). Therefore, given that the Peak of Excitement item includes two dimensions typically assessed in the state organization and state regulation factors, it is reasonable to allow it to load on both factors.

4.1. Creation of a self-organizing second-order factor

Although the original intention of the creators of the NBAS was to evaluate the factors derived from it independently, i.e., to describe and understand the range of variability in newborn behavior [1,33], we found high positive correlations among the six behavioral factors (with the exception of the Habituation and Motor System factors). This suggests that a second-order factor (Self-Organizing System) may be present. We evaluated this factor in Model 4b, which yielded the best fit, giving further support to this idea. Considering that the NBAS was "designed to describe the infant's adaptation and development, specifically the capacity for self-regulation" from birth to the end of the second month of life [4] (p. 4), we propose the concept of Self-Organizing System to describe this second-order factor.

The idea of a Self-Organizing System is strongly related to the notion of infant self-regulation and to the assumption that infants have certain inherent self-organizing and neurobehavioral capacities [34]. Brazelton gave a special attention to the way infants use states of consciousness to regulate internal and external stimuli and maintain an organizational homeostasis, which is typically indicated by self-regulation behaviors. In fact, the capacity for self-regulation is manifest across the four domains of neurobehavioral functioning (i.e., modulating autonomic or physiologic responses, motor behavior, states of consciousness and interactive behavior [4]), and nearly all of the NBAS items include a clear self-regulation component (Pull-to-Sit and General Tone being the most likely exceptions).

The Self-Organizing System score may be useful to future research or practice, because it can inform us about the global level of infants' adjustment to the extrauterine environment, including their capacity to integrate the different systems during the neonatal period. The positive correlations among the NBAS factors we observed, as well as the positive associations between NBAS factors and the Self-Organizing System factor, suggest that all domains of neurobehavioral functioning may be influenced by the process of hierarchical integration of infant behavior, as proposed by Als [35]. A Self-Organizing System score would thus reflect variations in infants' capacity for an organized response to maintain stability, and the integrated actions that infants use to regulate their internal states and exchanges with the environment, functioning as a self-organizing system that incorporates the six behavioral clusters.

Brazelton and Nugent [3] support the use of Lester's data reduction system, which assesses independent functions instead of a single summary score. We believe, however, that including both the independent domain (cluster) scores and a global summary index would broaden the possibilities of score interpretation and enhance flexibility in the use of the scale in research and clinical practice. For example, the Self-Organizing System score may facilitate the establishment of a clinical cut-off score, which can have important practical implications in prevention and intervention settings, although the NBAS was not designed as a normative test or diagnostic tool [3]. Further validation of this idea is warranted. In future research, investigators should obtain representative data from larger, more diverse samples of infants and establish norms for the Self-Organizing System and other NBAS scores. These data would allow for needed comparisons between individual infants and the general population of newborns. Cut-off scores might help identify infants who have poorer self-organization capacity at birth as well as those whose self-organizational skills are robust. Als [35] suggested that investigators and practitioners may scale neonates' functioning along three levels: superior, average, and worrisome. Higher scores on Self-Organizing System reflect an optimal self-organization (e.g., infant capacity to organize internal sates and external stimuli, easily achieving an optimal behavior with lower degrees of facilitation by the examiner). Inversely, lower scores on Self-Organizing System reflect difficulties in self-organization, thus indicating infants that may benefit from an intervention. The latter may be especially useful when the resources of the health system are scarce, and services have to establish treatment priorities. In such cases, the detailed clinical information gathered from the separate clusters would highlight the specific areas of neonatal functioning that would benefit most from an intervention. This procedure would complement Brazelton's recommendation of a complete neurological exam when three elicited reflexes scores are deviant in the NBAS.

4.2. Limitations and future research

Despite the good fit of Model 4b, these results should be considered preliminary and future studies should test the model in larger, more diverse samples of typical and at-risk newborns. On the other hand, because newborns' behavior is influenced by several intrauterine and environmental factors (e.g., length of labor, obstetric medication, gestational age, child-rearing practices and beliefs), and populations differ in these characteristics [5,36], our results might reflect natural variations related to the cultural and ethnic setting. In addition, the sample consisted of primarily low-risk highly educated Portuguese families, and the study focused on measurement during the first 72 h after birth, limiting the generalizability of the current results to other populations and to the remaining two months in which the NBAS can be administered. Replication of the proposed revised NBAS scoring in different samples, at other time periods during the first two months, and in other cultural settings is needed to confirm the reliability and stability of the results.

The inclusion of another observational measure of infant neurobehavior could also be important way to assess concurrent validity. Future studies could include other behavioral items that would help us understand the newborn behavior repertoire, and/or measures that would capture other domains of functioning (e.g., neurological, physiological, endocrine), allowing us to reach a better understanding of the neurobehavioral integrity of the newborn.

In sum, the results from the current study provide preliminary evidence to support a modified version of Lester's six behavioral clusters as a data reduction system for the NBAS items. The revised system should be particularly useful in the research setting, providing support for the use of both a global score and six separate behavioral cluster scores, with enhanced validity evidence. This information could also be helpful to practitioners in clinical applications with at-risk newborns.

Conflict of interest statement

None declared.

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