Development of the Comprehensive Observations of Proprioception (COP): Validity, Reliability, and Factor Analysis

Erna Imperatore Blanche, Stefanie Bodison, Megan C. Chang, Gustavo Reinoso

KEY WORDS
- developmental disabilities
- observation
- proprioception
- sensory motor performance
- somatosensory disorders

OBJECTIVE. We developed an observational tool, the Comprehensive Observations of Proprioception (COP), for identifying proprioceptive processing issues in children with developmental disabilities.

METHOD. Development of the COP underwent three phases. First, we developed items representing proprioceptive functions on the basis of an extensive literature review and consultation with occupational therapists. We then established interrater reliability and content, construct, and criterion validity. Finally, we completed a factor analysis of COP ratings of 130 children with known developmental disabilities.

RESULTS. Adequate validity and reliability were established. Factor analysis revealed a four-factor model that explained the underlying structure of the measure as it was hypothesized.

CONCLUSION. The COP is a valid criterion-referenced short observational tool that structures the clinician's observations by linking a child's behaviors to areas identified in the literature as relevant to proprioceptive processing. It takes 15 min to administer and can be used in a variety of contexts, such as the home, clinic, and school.

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Erna Imperatore Blanche, PhD, OTR/L, FAOTA, is Associate Professor, Division of Occupational Science and Occupational Therapy, University of Southern California, 1540 Alcazar, CHP–133, Los Angeles, CA 90089; blanche@usc.edu

Stefanie Bodison, OTD, OTR/L, is Postdoctoral Fellow, Division of Occupational Science and Occupational Therapy, University of Southern California, Los Angeles.

Megan C. Chang, PhD, OTR/L, is Assistant Professor, Department of Occupational Therapy, San José State University, San José, CA.

Gustavo Reinoso, PhD, OTR/L, is Director, Advance Therapy Systems, Dundalk, County Louth, Republic of Ireland.

Proprioception, defined as the sum of neuronal inputs from the joint capsules, ligaments, muscles, tendons, and skin, is a multifaceted system that influences behavior regulation and motor control (Ashton-Miller, Wojtys, Huston, & Fry-Welch, 2001; Ayres, 1972, 1989; Coleman, Piek, & Livesey, 2001; Ferrell et al., 2004; Grob, Kuster, Higgins, Lloyd, & Yata, 2002; Laszlo & Sainsbury, 1993; Lephart & Fu, 2000). Children with developmental disabilities often exhibit difficulties in processing proprioceptive information; however, few systematic evaluation tools are available that identify proprioceptive dysfunctions and help clinicians design precise intervention strategies to address them. The objectives of the study described in this article were to develop a new observational tool to identify proprioceptive processing disorders in children with developmental disabilities and to establish its validity and reliability.

Proprioception was originally defined by Nobel Prize–winning physician Charles Sherrington (1906) as the perception of joint movement and position in space. Its definition was later refined as kinesthesia (awareness of passive or active joint movement) plus position sense, comprising the sum of neuronal input from the joint capsules, ligaments, muscles, tendons, and skin (Ashton-Miller et al., 2001; Ayres, 1972; Grob et al., 2002; Lephart & Fu, 2000). Because proprioception affects the rate and timing of movements, the regulation of muscle force, and the regulation of muscle stretch (Kalaska, 1988;

Matthews, 1988; McCloskey, 1981), it affects children's ability to motor plan (Sober & Sabes, 2003), time their actions (Sainburg, Ghilardi, Poizner, & Ghez, 1995), maintain the fluidity of their movements, calibrate their actions in space, use feedback from the outcome of the action (Kalaska, 1994; McCloskey, 1981), stabilize their joints (Mackrous & Proteau, 2010; Riemann & Lephart, 2002), estimate their muscle force according to the task, and orient their body segments. (Bard, Fleury, Teasdale, Paillard, & Nougier, 1995; Ferrell et al., 2004; Gandevia, Refshauge, & Collins, 2002; LaRue et al., 1995; Laszlo & Bairstow, 1980).

Proprioception and Sensory Integration Theory

From a sensory integration perspective, Ayres (1972) described proprioception as influencing motor planning and modulation of level of arousal. She differentiated proprioception from kinesthesia and considered the former to be unconscious information from muscles and related structures and the latter to be conscious awareness of joint position and movement (Ayres, 1972, p. 67), a differentiation that is no longer made. Later writers added to the description of proprioception: Fisher (1991) described proprioception as being linked to vestibular processing disorders and feed-forward mechanisms, Dunn (1999) linked proprioception to sensory-seeking behaviors, and Blanche and Schaaf (2001) linked proprioception to both tactile and vestibular processing disorders and to motor-planning and sensory-seeking behaviors.

Clinicians presently use three methods to collect information about proprioception: (1) the Kinesthesia (KIN) and Standing and Walking Balance (SWB) tests of the Sensory Integration and Praxis Tests (SIPT; Ayres, 1989); (2) parent report of behaviors theoretically linked to proprioceptive functions, such as the Sensory Profile (SP; Dunn, 1999) and the Sensory Processing Measure Home Form (SPM–Home Form; Parham & Ecker, 2007); and (3) unstructured observations of the child's behaviors (Blanche, 2002, 2006; Blanche & Reinoso, 2008). These tools present several problems, however. The KIN test provides a standardized measure of only one aspect of proprioceptive abilities, and the SWB test is a measure of proprioceptive and vestibular abilities and therefore is not a pure measure of proprioception; the SP and SPM–Home Form depend on a parent's or teacher's perception of abilities that relate to proprioceptive processing; and the unstructured observations rely on the clinician's understanding of proprioception. The results obtained from these methods of gathering information do not always correspond because they measure the impact of proprioception on two different areas of performance: motor performance and regulation of behavior. The tool described in this article organizes the clinician's observations by providing a structured way to measure the relationship of proprioception to motor performance and to arousal modulation; this tool is intended to accompany other forms of gathering information such as those listed previously.

Method

The Comprehensive Observations of Proprioception (COP) is a criterion-based observational tool we originally constructed to measure two main areas of proprioceptive functions: behavior and sensory–motor abilities. The tool also includes two items described in the literature as related to proprioception: muscle tone and hypermobility (Ferrell et al., 2004). The COP is an observational tool that takes 15 min to administer while the clinician observes the child during free play. We collected data from existing charts in two clinics in the Los Angeles area after obtaining approval from the University of Southern California institutional review board (IRB).

Phase 1: Construction of the Questionnaire and Content Validity

For the construction of the questionnaire, we drew from the current literature on proprioceptive functions and dysfunctions and a survey of practitioners' methods of assessing proprioception. The literature we reviewed focused primarily on proprioceptive functions related to motor performance, but the occupational therapy literature and practitioners also included a second dimension of proprioception: behavioral manifestations of sensory seeking.

The existing literature has described proprioceptive functions associated with sports injuries (Beynnon, Good, & Risberg, 2002; Dover, Kaminski, Meister, Powers, & Horodyski, 2003; Dover & Powers, 2003), schizophrenia (Chang & Lenzenweger, 2005; Picard, Amado, Mouchet-Mages, Olié, & Krebs, 2008), joint hypermobility syndrome (Ferrell et al., 2004), idiopathic scoliosis (Keessen, Crowe, & Hearn, 1992), clumsiness and developmental coordination disorder (Ayres, 1972; Coleman et al., 2001; Laszlo & Bairstow, 1980; Sigmundsson, Whiting, & Ingvaldsen, 1999), autism spectrum disorders and Asperger syndrome (Weimer, Schatz, Lincoln, Ballantyne, & Trauner, 2001), and deficits in visual perception and oculomotor control (Ayres, 1972). Proprioception has also been reported to influence the rate and timing of movements, the regulation of muscle force, and the regulation of muscle stretch (Kalaska, 1988; Matthews, 1988; McCloskey, 1981), all of which can affect motor control. Other motor abilities linked to proprioception include motor programming, postural control, fluidity of movement, calibration of spatial frame of reference, feedback from outcome of motor commands, joint stability, conscious estimation of muscle force, and orientation of body segments or body scheme (Bard et al., 1995; Ferrell et al., 2004; Gandevia et al., 2002; LaRue et al., 1995; Laszlo & Bairstow, 1980). We included items representing each of these areas of performance in the COP (Table 1).

Phase 2: Establishment of Validity and Reliability

We established face and content validity following the recommendations outlined by Goldsmith (1993) and Portney and Watkins (2009). A panel of nine occupational therapists who were experts in sensory integration rated each item of the pilot version of the questionnaire as +1 = *item is a definite measure of proprioception,* 0 = *undecided as to whether the item is a measure of proprioception,* and −1 = *item is not a measure of proprioception.*

On the basis of the expert review, we modified the scale, retaining items identified as strong (index ≥ .70) or adequate (.60 < index ≤ .69). The expert panel also identified five items in the structured clinical observations that they considered to be related to proprioceptive processing: (1) arms come down during Schilder's arm extension test (Schilder, 1931; Silver & Hagin, 1960), (2) lack of fluidity or inability to maintain pace during slow ramp movements, (3) finger does not reach tip of nose during finger-to-nose task, (4) poor performance in the sequential finger-touching test, and (5) poor performance during alternating movements. The experts rejected four items they did not consider to be related to proprioception: (1) feedback-related motor-planning skills are inappropriate for age, (2) feed forward–related motor-planning skills are inappropriate for age, (3) child is overactive, and (4) child is passive. We left these items in the scale, however, because the literature supported their inclusion.

On the basis of the expert analysis, we eliminated five other items from the scale: (1) muscle tone is hypotonic, (2) increased muscle tone, (3) muscle tone is symmetrically distributed, (4) muscles appear well delineated, and (5) inability to copy simple movements. Clinicians completing the scale were instructed to answer each item using a Likert scale of 1 = *typical performance* to 5 = *most severe form of proprioceptive processing difficulties* that can be observed in children diagnosed as developmentally

Table 1. Comprehensive Observations of Proprioception Items and Support From Relevant Literature

Item No.	Item	Support From the Literature
1	Decreased muscle tone	Bergenheim, Johansson, Pedersen, Ohberg, & Sjölander, 1996; Johansson, Bergenheim, Djupsjöbacka, & Sjölander, 1995
2	Joint hypermobility	Ferrell et al., 2004
3	Poor joint alignment and cocontraction	Lephart & Fu, 2000; Riemann & Lephart, 2002
4	Inefficient ankle strategies	Gatev, Thomas, Kepple, & Hallett, 1999; Horak, Nashner, & Diener, 1990; Runge, Shupert, Horak, & zajac, 1999
5	Inadequate weight-bearing and weight-shifting patterns	Ashton-Miller et al., 2001
6	Decreased postural control	Ghez, 1991
7	Decreased feedback-related motor planning abilities	Sober & Sabes, 2003
8	Decreased feed forward–related motor planning abilities	Dunn, Gillig, Ponsor, Weil, & Utz, 1986; Gatev et al., 1999; Ghez, 1991
9	Inefficient grading of force	Lafargue, Paillard, Lamarre, & Sirigu, 2003
10	Decreased fluidity of movements (not included in factor analysis)	Mackrous & Proteau, 2010
11	Decreased midrange control (not included in factor analysis)	Lephart, Pincivero, & Rozzi, 1998
12	Tiptoeing	Wick & zanni, 2010
13	Pushing others or objects	Parham & Ecker, 2007
14	Enjoyment when being pulled	Blanche, 2006; Blanche & Reinoso, 2008
15	Tendency to lean on others	Ayres, 1972; Parham & Ecker, 2007
16	Overactive	Parham & Ecker, 2007
17	Overpassive	Blanche & Reinoso, 2008
18	Crashing, falling, running	Dunn, 1999; Dunn & Brown, 1997

delayed, excluding children with cerebral palsy or genetic disorders because this scale was not designed for use with those populations.

We established construct validity by reviewing the charts of 24 children (7 girls, 17 boys) with known problems (P group) and comparing their performance on the COP with the performance of 20 children without proprioceptive difficulties (NP group) matched by age (mean 6 yr, 7 mo; range 2 yr to 8 yr, 11 mo);. One of the primary investigators of this study (Bodison) rated the children without proprioceptive difficulties using the COP during play activities in a public setting, as specified by IRB procedures.

We established criterion validity by comparing the P group's results on the Body Awareness section of the Sensory Processing Measure Home Form (Parham & Ecker, 2007) and the Kinesthesia and Standing and Walking subtests of the Sensory Integration and Praxis Tests (Ayres, 1989) with their performance on the COP. The SIPT and the SPM–Home Form are commonly used in pediatric practice to evaluate the sensory functions of children. The SIPT is a norm-referenced standardized assessment occupational therapists use to determine the underlying sensory processing problems that might be affecting a child's occupational performance. The SPM–Home Form is a parent-completed questionnaire that allows caregivers to communicate their observations of the child's difficulties in everyday tasks; the Body Awareness items included in our analysis are presented in Table 2. We analyzed the chart review results using Pearson's bivariate correlations to explore whether the COP was measuring proprioceptive functions as accurately as the two measures of proprioception commonly used in pediatric practice.

Phase 3: Factor Analysis

To aid in the process of ongoing construct validation (Portney & Watkins, 2009), we conducted an exploratory factor analysis (EFA) with oblique rotation. We collected data from 130 children with a diagnosis of developmental delay aged 2–9 yr. We hypothesized that the underlying structure of the variables would reflect the dimension of the scale—that is, tone and mobility, motor skills, and behavioral manifestations. Table 3 displays the results from the EFA.

Results

Construct Validity

The children with developmental disabilities (P group) had significantly higher scores on the COP than the children in the NP group in the total scores and in all individual items (all *p*s $< .01$) except Item 17 (overpassive; $p = .12$). These results indicate that the P group exhibited proprioceptive difficulties that were identified by the COP and that this observational tool differentiates between children with and without proprioceptive difficulties.

Criterion Validity

The three right columns of Table 3 present the results of the Pearson's correlation analysis comparing individual COP items with the Kinesthesia and the Standing and Walking tests from the SIPT and the Body Awareness section items of the SPM–Home Form for the 24 children with known delays in developmental abilities. Among the COP items correlating with the SIPT subtests, only Item 9 (inefficient grading of force) correlated significantly with KIN, whereas four items in the COP (Items 4, inefficient ankle strategies; 9, inefficient grading of force; 10, decreased fluidity of movements; and 15, tendency to lean) correlated significantly with SWB. Additionally, Items 2 (joint hypermobility), 1 (decreased muscle tone), 4 (inefficient ankle strategies), and 5 (inadequate weight-bearing patterns) correlated marginally with KIN, and Item 7 (decreased feedback-related motor

Table 2. Body Awareness Items in the Sensory Processing Measure Home Form

Item No.	Does your child . . .
46	Grasp objects (such as a pencil or spoon) so tightly that it is difficult to use the object?
47	Seem driven to seek activities such as pushing, pulling, dragging, lifting, and jumping?
48	Seem unsure how far to raise or lower the body during movement such as sitting down or stepping over an object?
49	Grasp objects (such as a pencil or spoon) so loosely that it is difficult to use the object?
50	Seem to exert too much pressure for the task, such as walking heavily, slamming doors, or pressing too hard when using pencils or crayons?
51	Jump a lot?
52	Tend to pet animals with too much force?
53	Bump or push other children?
54	Chew on toys, clothes, or other objects more than other children do?
55	Break things from pressing or pushing too hard on them?

Table 3. Factor Loadings for Exploratory Factor Analysis and Correlations With Items From the SPM and SIPT

		EFA With Oblique Rotation						
Factor	COP Item	F1	F2	F3	F4	KIN (SIPT)	SWB (SIPT)	BOD (SPM)
1. Tone and joint alignment	2. Joint hypermobility	**.822**	.079	−.021	−.104	−.37		
	1. Decreased muscle tone	**.774**	−.037	−.086	.154	−.37		
	3. Poor joint alignment	**.674**	.018	.164	.093			
2. Behavioral manifestations	13. Pushing	−.013	**.752**	.094	.125			
	16. Overactive	−.065	**.629**	.061	−.305			
	18. Crashing, falling, running	.070	**.694**	.136	−.064			Item 49: .63* Item 53: .44*
	14. Enjoyment when pulled	.067	**.671**	−.126	−.038			Item 53: .44*
	12. Tiptoeing	−.041	**.453**	−.161	.288			
3. Postural motor	6. Decreased postural control	−.045	−.116	**.758**	.154			Item 55: .47*
	15. Tendency to lean	.116	.026	**.696**	−.078		−.46*	Item 49: .47* Item 52: .48* Item 53: .41*
	9. Inefficient grading of force	−.047	.349	**.525**	.086	−.41*	−.41*	
	5. Inadequate weight bearing	.440	−.150	**.501**	.027	−.38	−.39	
	4. Inefficient ankle strategies	.296	.052	**.404**	.214	−.37	−.49*	
4. Motor planning	7. Decreased feedback planning	.077	.089	.104	**.733**	−.39	−.38	
	8. Decreased feed-forward planning	.097	.132	.159	**.530**		.36	
	17. Overpassive	.035	−.272	.089	**.472**			

Note: Negative correlations with KIN and SWB reflect measurement differences; higher scores on the COP and BOD correspond to more severe dysfunction, whereas higher scores on KIN and SWB correspond to lesser severity. Boldface numbers represent significant loadings on each factor; blank cells indicate no significant correlation. BOD = Body Awareness section; COP = Comprehensive Observations of Proprioception; EFA = exploratory factor analysis; F = factor; KIN = Kinesthesia test; SIPT = Sensory Integration and Praxis Tests; SPM = Sensory Processing Measure–Home Form; SWB = Standing and Walking Balance test.
*$p < .05$.

planning) correlated marginally with KIN and SWB. All correlations between the SIPT tests and the COP are negative, suggesting that children who have more difficulties in SWB also have more difficulties processing proprioception.

COP Items 18 (crashing, falling, running), 14 (enjoyment when being pulled), 6 (decreased postural control), and 15 (tendency to lean) correlated significantly with BOD Items 49 (grasp loosely), 52 (use too much force with animals), 53 (bump or push other children), and 55 (break things from pressing or pushing too hard on them), indicating that the COP targets some proprioceptive functions that are related to body awareness as measured by the SPM. The correlational analyses of the COP with these two tests thus support the use of the COP as an observational tool measuring two distinct influences of proprioceptive functions: motor performance and sensory seeking.

Interrater Reliability

To examine preliminary interrater reliability, four occupational therapists who had a minimum of 2 yr of experience and who had received a 15-min training on the COP rated four 20-min videotaped evaluation and regular treatment sessions of children who had been identified as having proprioceptive difficulties. We examined each item individually using the κ statistic for multiple cases and raters because the responses were categorical (*always, most of time, sometimes, rarely, never;* Fleiss, 1971, 1981). The overall κ statistic is .62, which indicates substantial agreement among the raters beyond chance. Next, to examine reliability for total scores, we converted the responses numerically before calculating the intraclass correlation coefficient (ICC). The total score revealed an ICC of .91, indicating that variation among the four raters was minimal. In summary, occupational therapists who have at least 2 yr of clinical experience can reliably administer the COP to children referred to occupational therapy because of motor and behavioral difficulties.

Exploratory Factor Analysis

Table 3 displays factor loadings from the exploratory factor analysis and correlations of COP items with items from the SPM and SIPT. The negative correlations with KIN and SWB are attributable to measurement differences; higher scores on the COP and BOD correspond to more severe dysfunction, whereas higher scores on the KIN and SWB correspond to lesser severity. Results of the factor analysis revealed four factors: Tone and Joint Alignment (Factor 1), Behavioral Manifestations (Factor 2), Postural Motor (Factor 3), and Motor Planning (Factor 4).

Factor 1 loads with proprioceptive items targeting muscle tone and proximal joint stability or cocontraction. This factor focuses on what has been described as spinal functions related to proprioception.

Factor 2 loads with items that are often viewed as behavioral manifestations of proprioceptive seeking. Its items correlate significantly with Items 49 (grasp objects loosely) and 53 (bump or push other children) of the SPM, supporting the relationship between therapists' and parents' observations of behavioral difficulties related to proprioception.

Factor 3 loads with items that target components of adequate postural control. One item of the COP (Item 6, decreased postural control) correlated significantly with Item 55 of the SPM (break things from pressing or pushing too hard on them); another item of the COP (Item 15, tendency to lean) correlated significantly with Items 49, 52, and 53 of the SPM and with SWB. This factor represents postural and motor performance difficulties related to proprioceptive functioning.

Factor 4 loads with items that represent motor planning. Item 7 (decreased feedback-related motor planning) correlated marginally with KIN and SWB, and Item 8 (decreased feed forward–related motor planning) correlated marginally with SWB, supporting the relationship between feed-forward actions and postural control as related to proprioceptive functions (Fisher, 1991). The items in this factor did not correlate significantly with any of the body awareness items of the SPM, suggesting that this factor is measuring some aspects of proprioception as it relates to motor planning. Future studies need to focus on correlating these items of the COP with the Postural Praxis and Sequencing Praxis subtests of the SIPT.

Discussion

Our protocol for measuring proprioceptive functions is designed to complement, rather than replace, existing measures of proprioception. The COP joins two aspects of proprioceptive processing usually measured separately: (1) behavioral manifestations related to arousal modulation and sensory seeking and (2) sensory–motor abilities related to poor body awareness and hyporresponsiveness to proprioception. The benefits of the COP lie in its contribution as a behavioral observation tool that can support clinical practice. Its correlation to existing measures targeting proprioception suggests that well-trained therapists can effectively apply observational measures in their assessment of proprioceptive functions. Moreover, the exploratory factor analysis suggests that functions that traditionally have been considered sensory–motor functions can be further differentiated into functions related to postural control, muscle tone and mobility, and motor planning, contributing to our understanding of proprioceptive functions.

Implications for Occupational Therapy Practice

The results of this study indicate that the COP

- Is a quick, easy-to-administer, criterion-referenced observational assessment tool that can be completed while the child is engaged in free-play;
- Provides clinicians with valid information about the child's proprioceptive processing issues that may be interfering with functional performance across multiple environments; and
- Is designed to supplement regularly used standardized measures of proprioception commonly used in pediatric practices.

Conclusion

A limitation of this study is that the data were collected using a sample of convenience from one region of the country. The results obtained from this study need to be confirmed in studies of larger populations. We anticipate that the COP will be useful in clinical practice to screen clients and assess therapeutic interventions in different settings. ▲

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