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Beginning to disentangle the prosody-literacy relationship: a multi-component measure of prosodic sensitivity

A. J. Holliman · G. J. Williams · I. R. Mundy · C. Wood · L. Hart · S. Waldron

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Abstract A growing number of studies now suggest that sensitivity to the rhythmic patterning of speech (prosody) is implicated in successful reading acquisition. However, recent evidence suggests that prosody is not a unitary construct and that the different components of prosody (stress, intonation, and timing) operating at different linguistic levels (word, phrase, and sentence) may be related to reading development in different ways. Sixty-two five- to seven-year-old English-speaking children completed a newly developed, multi-component measure designed to assess several different aspects of prosodic sensitivity in a single, easily-administered task. The new measure was found to be sensitive to individual differences in prosodic sensitivity and participants' overall scores were significantly correlated with measures of vocabulary, phonological awareness, phonological decoding, text reading accuracy, and reading comprehension. An exploratory factor analysis suggested that the multi-component measure of prosodic sensitivity distinguished between the processing of stress, intonation, and timing. The task also distinguished between word-level and sentence-level sensitivity to stress information. These findings add to the growing literature demonstrating a relationship between prosodic sensitivity and reading and represent a first step towards disentangling prosody and developing a more sophisticated understanding of its role in early reading development.

A. J. Holliman (✉) · I. R. Mundy · C. Wood · L. Hart · S. Waldron
Faculty of Health and Life Sciences, Coventry University, Priory Street, Coventry CV1 5FB, UK
e-mail: a.holliman@coventry.ac.uk

I. R. Mundy
e-mail: ian.mundy@coventry.ac.uk

C. Wood
e-mail: clare.wood@coventry.ac.uk

G. J. Williams
Division of Psychology, Nottingham Trent University, Burton Street, Nottingham NG1 4BU, UK
e-mail: gareth.williams@ntu.ac.uk

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Introduction

It is well established that awareness of phonological segments such as phonemes and rhymes is a strong, proximal predictor of reading ability (e.g., Goswami & Bryant, 1990; Muter, Hulme, Snowling, & Taylor, 1998; Ziegler & Goswami, 2005). However, in recent years, researchers have argued that sensitivity to speech prosody may also make a significant contribution to literacy development (e.g., Clin, Wade-Woolley, & Heggie, 2009; Goswami et al., 2002; Goswami, Gerson, & Astruc, 2009; Gutierrez-Palma & Reyes, 2007; Holliman, Wood, & Sheehy, 2008; 2010a, b, 2012; Leong, Hämäläinen, Soltész, & Goswami, 2011; Schwanenflugel, Hamilton, Kuhn, Wisenbaker, & Stahl, 2004; Whalley & Hansen, 2006; Wood, 2006; Wood & Terrell, 1998).

Prosody refers to the rhythmic patterning of spoken language. One type of rhythmic patterning results from variations in stress assignment across the syllables in a word or phrase; for example, contrast the strong–weak stress pattern of the noun 'REcord' with the weak-strong stress pattern of the verb 'reCORD'. Another type of rhythmic patterning results from the shape of the intonation contour across the syllables in words or phrases; for example, contrast */finished* (ending with a rise in intonation and implying a question) with *\finished* (ending with a fall in intonation and implying a statement). Yet another type of rhythmic patterning is timing; for example, variations in pause duration may help a listener discriminate between compound nouns (e.g., ice-cream) and noun phrases (e.g., ice, cream).

Broadly speaking, three types of study have demonstrated a relationship between prosodic sensitivity and literacy ability. Firstly, it has been demonstrated that sensitivity to the low-level acoustic correlates of speech prosody predicts segmental phonological awareness (e.g., Goswami et al., 2002; Kuhl, 2004). Participants in these studies are typically required to detect frequency or amplitude modulations in non-speech stimuli or make same/different judgments on pairs of tones with varying modulation depths or amplitude rise times. Adults and children with dyslexia are also found to be impaired on these tasks (e.g., Corriveau, Pasquini, & Goswami, 2007; Goswami et al., 2009; Muneaux, Ziegler, Truc, Thomson, & Goswami, 2004; Pasquini, Corriveau, & Goswami, 2007; Richardson, Thomson, Scott, & Goswami, 2004; Thomson, Fryer, Maltby, & Goswami, 2006). A closely related literature has demonstrated that awareness of speech prosody in language stimuli has a direct relationship with literacy performance that is independent of segmental phonological awareness (e.g., Clin et al., 2009; Holliman et al., 2008, 2010a, b, 2012; McBride-Chang et al., 2008; Whalley & Hansen, 2006; Wood, 2006). Participants in these studies are most often required to match filtered or re-iterative speech to one of several spoken words, phrases or sentences, indicate the syllable carrying primary stress within a word, or make same/different judgments on pairs of words with varying patterns of stress assignment. As with the low-level processing of acoustic cues to stress, children and adults with dyslexia are found to be impaired on these tasks (e.g., Goswami et al., 2009; Kitzen, 2001; Leong et al., 2011; McBride-Chang et al., 2008). Finally, while the majority of existing studies focus on syllabic stress and its acoustic correlates, a further research literature has also suggested a role for the processing of intonation in reading development (e.g., Cheung et al., 2008; McBride-Chang et al., 2008a, b; Schwanenflugel et al., 2004; Shu, Peng, & McBride-Chang, 2008).

Recent findings have suggested that the different components of prosody introduced above—stress, intonation, and timing—may be related to reading development in different ways. For instance, stronger links have been found between intonation and comprehension than between timing (defined as the number of inappropriate pausal intrusions during passage reading) and comprehension (e.g., Miller & Schwanenflugel, 2006; Ravid & Mashraki, 2007). Furthermore, these different types of prosodic sensitivity can be applied at a variety of linguistic levels. For example, prosodic patterns emerging from differences in syllabic stress assignment may occur at the word-level or higher levels such as the phrase- or sentence-level.

At the word level, prosodic sensitivity has been shown to be significantly associated with spelling ability (Wood, 2006) and reading ability (Whalley & Hansen, 2006; Wood, 2006). It has also been associated with vocabulary levels in Dutch monolingual children (Goetry, Wade-Woolley, Kolinsky, & Mousty, 2006), and non-word reading in Spanish children (Gutierrez-Palma & Reyes, 2007). In comparison, phrase/sentence-level prosodic sensitivity has been associated with reading comprehension (Whalley & Hansen, 2006). Furthermore, Clin et al. (2009) found an association between sentence-level prosodic sensitivity and morphological awareness.

This brief literature review suggests that the key challenge currently facing researchers studying the role of prosodic skills in reading development is to identify the different types of prosodic sensitivity that exist and demonstrate their independent links to different aspects of the reading process. The need to disentangle the various prosody-literacy associations has been acknowledged by a number of researchers (e.g., Holliman et al., 2010a; Miller & Schwanenflugel, 2006). However, the field currently lacks an easily-administered task, suitable for use with young children, which can provide measures of all aspects of prosodic sensitivity. The current study aims to address this issue by introducing and evaluating a novel, multi-component measure of prosodic sensitivity. To our knowledge, this task is the first to assess the different types of prosodic sensitivity (stress, intonation, and timing) across several different linguistic levels (word, phrase, and sentence).

This was primarily an exploratory study aimed at evaluating the new measure of prosodic sensitivity. The study had four specific aims: to determine whether this relatively complex multi-component measure of prosodic sensitivity could be successfully administered to a sample of beginning readers; to establish that the new measure was able to detect individual differences in prosodic sensitivity; to establish that overall task performance on the new measure correlated significantly with reading ability and measures of phonological processing; and to investigate the extent to which the task was able to provide measures of distinct prosodic skills operating at different linguistic levels. Of particular interest, was the sensitivity of the multi-component task to the distinctions between stress, intonation, and timing as well as between word- and sentence-level processing identified elsewhere in the literature. The answers to these questions would determine the future ability of the task to measure different aspects of prosodic sensitivity and investigate their independent links to specific aspects of the reading process.

Method

Participants

All participants ($N = 62$, 30 males) were recruited from year 1 ($n = 27$) and year 2 ($n = 35$) classes at a single primary school in the West Midlands, UK. Children were aged between 5 years 10 months and 7 years 4 months (mean age 6 years 3 months). All of the children had English as their first language.

Measures

Criterion measures were chosen on the basis that they have been standardised for the UK population and are widely used in the education literature (c.f., Cain & Oakhill, 2006; Holliman et al. 2008, 2010a; Muter & Diethelm, 2001; Wood, 2002).

General ability measures

Non-verbal IQ was measured using the Coloured Progressive Matrices subtest of Raven's IQ scale (Raven & Rust, 2008). Children were required to complete a series of patterns by choosing the best-fitting piece from a choice of four response options. Raven and Rust report internal reliability (Cronbach's α) of .97.

Verbal IQ was measured using the Crichton Vocabulary subtest of Raven's IQ scale (Raven & Rust, 2008). Children were presented with a series of written words that were also read aloud by the administrator and were asked to explain what each word meant. Raven and Rust report internal reliability (Cronbach's α) of .96.

Phonological processing measures

Phonological awareness was measured using the Rhyme Detection subtest of the Phonological Assessment Battery (Frederickson, Frith, & Reason, 1997). Children were required to verbally identify the two rhyming words from a choice of three (e.g., 'Red', 'Fed', and 'Leg') that were read aloud by the administrator. Frederickson et al. report internal reliability (Cronbach's α) of .92.

Phonological decoding was measured using the Non-Word Reading subtest from the Phonological Assessment Battery (Frederickson et al., 1997). Children were presented with a list of 20 non-words (e.g., yutmip) of increasing difficulty and were asked to read aloud as many items as they could. Frederickson et al. report internal reliability (Cronbach's α) of .95.

Prosodic sensitivity was assessed using a novel measure developed by the first author, which provided a detailed measure of prosodic sensitivity by assessing children's sensitivity to three different components of speech prosody (stress, intonation, and timing) at three different linguistic levels (word, phrase, and sentence).

All conditions of this task involved the same cartoon character, introduced to the children as *Dina the Diver*. During each trial, *Dina* would say a series of words, phrases, or sentences either above the water (resulting in clearly and correctly sounded utterances) or under the water (resulting in utterances with no identifiable phonemic content but a preserved prosodic contour). These utterances were produced by low-pass filtering pre-recorded words, phrases, and sentences using Sound Forge Audio Studio 9.0. The audio files were presented to the children accompanied by images of *Dina* entering or exiting the water. The spoken utterances included character names and scenes from popular storybooks, cartoons and children's television programmes.

Trials measuring sensitivity to stress began by presenting the children with two cards, each of which depicted a character or scene from a storybook, cartoon, or television programme. Children then heard *Dina* produce two utterances (one relating to each card) clearly and correctly over a computer speaker. Following this, children heard *Dina* repeat one of the utterances under water and were asked to identify what *Dina* was trying to say by pointing to the picture on the corresponding card. This forced choice procedure was used at the word-level (e.g., alADDin versus TINkerbell), phrase-level (e.g., WInnie the POOH versus HUMpty DUMpty), and sentence-level (e.g., DOra LOVES to expLORE versus BUGS BUNny likes CArrots).

During trials assessing sensitivity to intonation, children were presented with a card depicting a recognisable character or scene from a storybook, cartoon, or television programme. Children then heard *Dina* produce a corresponding utterance clearly and correctly. Using a procedure inspired by Hadding and Studdert-Kennedy (1974), the utterances were produced either with a rise in intonation at the end to imply a question (e.g., /Godzilla) or with a fall in intonation at the end to imply a statement (e.g., \Godzilla). Children were asked to identify whether *Dina* was 'telling' or 'asking' them about the character or scene depicted on the card. This forced choice procedure was used at the word-, phrase-, and sentence-level.

During the trials assessing sensitivity to syllable timing, children heard *Dina* repeat one of the utterances twice under water. On some trials, *Dina* produced the utterances in exactly the same way (e.g., Spiderman-Spiderman) while on others the utterances differed in terms of initial syllable duration (e.g., Spiderman-Spiiiiider-man). The syllable lengthening effect was achieved by editing the low-pass filtered words, phrases, and sentences using PRAAT (Boersma, 2001). In contrast to previous studies (e.g., Miller & Schwanenflugel, 2006; Ravid & Mashraki, 2007), which have focused on pause duration as an index of timing, the manipulation in this task involved variation in syllable duration. Children were asked to identify whether the two utterances were the same or different. This forced choice procedure was used at the word-, phrase-, and sentence-level.

There were two practice trials and five test trials assessing sensitivity to each prosodic component (stress, intonation, and timing) at each linguistic level (word, phrase, and sentence). Children received one point for each correct answer and obtained a score out of five for each condition of the task as well as an overall prosodic sensitivity score out of 45. The stimuli and scoring sheet used during this task are presented in the "Appendix". The task was administered on two separate occasions (3 months apart) to a small subsample of participants so that test–retest reliability could be calculated. This was found to be good ($r = .781$, $p = .013$). Also, to check the internal reliability of the measurement obtained in this sample, Cronbach's α reliability coefficient was calculated and found to be fair, $\alpha = .57$.

Literacy measures

Text reading and comprehension were measured using the Revised Neale Analysis of Reading Ability (NARA II, Neale, 1997). Following a practice passage, children were required to read aloud up to six passages of increasing difficulty as quickly and as accurately as possible. The administrator recorded the number of decoding errors that were made on each passage. At the end of each passage, children were asked a series of open-ended comprehension questions. Neale reports internal reliability (Cronbach's α) of .82 for reading accuracy and .93 for comprehension.

Procedure

Information sheets and opt-out consent forms were delivered to the parents of participating children via the school. Data were collected over a 5 month period during the winter term of 2010 and the spring term of 2011 by a single research assistant who was employed specifically for this purpose. The research assistant was educated to Master's Level and had experience working as a research assistant and co-project manager on a range of fully funded literacy projects. There were a total of seven assessments administered in a fixed order over three sessions. *Dina the Diver* was administered in the first session. The Raven's IQ subtests (matrix reasoning and vocabulary) were administered in the second session. The segmental phonological tests (rhyme detection and non-word reading) and the NARA II for text reading accuracy and reading comprehension were administered in the third session.

Results

Preliminary analyses

Descriptive statistics for all assessments are presented in Table 1. Sample means were in the average range for the standardised measures of matrix reasoning, vocabulary, phonological awareness, phonological decoding, text reading accuracy and reading comprehension. A χ^2 analysis, $\chi^2(1, N = 62) = 20.903$, $p < .001$, indicated that a significant number of participants were performing above chance on the *Dina the Diver* task (overall composite). The number of participants performing above chance for each of the prosodic components (max score: $3 \times 5 = 15$) was also statistically significant for intonation: $\chi^2(1, N = 62) = 10.903$, $p = .001$, timing: $\chi^2(1, N = 62) = 12.645$, $p < .001$, but not stress: $\chi^2(1, N = 62) = 2.323$, $p = .128$. Moreover, measures of dispersion ($SD = 4.57$; range = 20) indicated substantial variability in performance within the sample with no evidence of significant skewness ($z = 1.3$) or kurtosis ($z = -.2$).

Correlation analyses

Bivariate correlations between the measures of matrix reasoning, vocabulary, phonological awareness, phonological decoding, text reading accuracy, and reading comprehension and prosodic sensitivity (overall score /45) are presented in Table 2. It can be seen from Table 2 that prosodic sensitivity was significantly correlated with all phonological and reading measures in this study. However, it was important to demonstrate that this relationship persists after controlling for general ability measures and therefore partial correlations controlling for matrix reasoning and vocabulary were also calculated. After controlling for vocabulary size and non-verbal IQ, participants' overall level of prosodic sensitivity was still significantly correlated with phonological awareness ($pr = .41$, $p = .001$), phonological decoding ($pr = .27$, $p = .034$), text reading accuracy ($pr = .27$, $p = .04$) and reading comprehension ($pr = .27$, $p = .036$).

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Participants' scores (/5) for each condition of the *Dina the Diver* task (i.e., stress-word, stress-phrase, stress-sentence, intonation-word, intonation-phrase, intonation-sentence, timing-word, timing-phrase, and timing-sentence) were entered into an exploratory factor analysis. The sample size of ~ 7 participants per variable was clearly small, but importantly, the Kaiser–Meyer–Olkin value was .529 and Bartlett's Test of Sphericity was significant, χ^2 $(1, N = 62) = 20.903$, $p = .008$, indicating that our data met the minimum requirements for a factor analysis (Kaiser, 1974, cited in Field, 2009, p. 659). All of the variables were normally distributed and there was no evidence of multicollinearity. The largest correlation between any pair of variables was moderate ($r = .549$, $p < .001$). The method used for factor extraction was principle component analysis and the rotation method was varimax with Kaiser normalisation. Table 3 shows the results from the factor analysis.

Four factors with eigenvalues greater than 1 were identified. These explained 23.1, 14.5, 13.4 and 11.9 % of the variance respectively. Factor 1 comprised word-,

Table 1 Summary statistics for children on measures of prosodic sensitivity, general ability, phonological processing, and reading

Task	Mean	Std. deviation
Prosody/45	25.9	4.57
Matrix reasoning/36	19.58	4.4
Vocabulary/80	21.1	6.86
Rhyme detection/21	10.47	5.54
Non-word reading/20	10.4	4.33
Text reading accuracy/NA	19.56	14.56
Reading comprehension/NA	5.1	4.79

The mean scores presented above are 'raw scores' with each equating to a mean standardised score between 96 and 107 in the 'average score' range

Table 2 Bivariate correlations between prosodic sensitivity, general ability, phonological processing, and reading

Variables	1	2	3	4	5	6
1. Prosody	–					
2. Matrix reasoning	.14	–				
3. Vocabulary	.42**	.31*	–			
4. Rhyme detection	.44***	.44***	.27*	–		
5. Non-word reading	.35**	.29*	.28*	.62***	–	
6. Text reading accuracy	.37**	.38**	.36**	.66***	.76***	–
7. Reading comprehension	.42**	.32*	.51***	.57***	.63***	.89***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 3 Rotated factor matrix showing factor loadings for the different components of prosody at different linguistic levels

	Factor 1	Factor 2	Factor 3	Factor 4
Intonation; phrase-level	.777			
Intonation; word-level	.772			
Intonation; sentence-level	.689			
Timing; word-level		.785		
Timing; phrase-level		.711		
Stress; word-level			.865	
Stress; sentence-level				.674
Timing; sentence-level				.620
Stress; phrase-level			.520	

phrase-, and sentence-level processing of intonation, with factor loadings ranging from .689 to .777; Factor 2 comprised word- and phrase-level processing of syllable timing, with factor loadings of .785 and .711 respectively, and Factor 3 comprised word- and phrase-level processing of stress, with factor loadings of .865 and .520 respectively. Finally, Factor 4 comprised sentence-level processing of both stress and syllable timing, with factor loadings of .674 and .620 respectively.

Discussion

This study aimed to evaluate a novel, multi-component measure of prosodic sensitivity. This was intended as a first step towards a more systematic understanding of the associations between distinct components of prosodic sensitivity and specific aspects of literacy. The task provided a detailed measure of prosodic sensitivity by assessing children's sensitivity to three different components of speech prosody (stress, intonation, and timing) at three different linguistic levels (word, phrase, and sentence).

The study had four specific aims. Most fundamentally, it was necessary to determine whether a relatively complex, multi-component measure of prosodic sensitivity could be successfully administered to beginning readers. The mean overall score and the scores for each prosodic component were all found to comfortably exceed the chance level thus confirming that the task was not prohibitively difficult for the young children in this sample.

Secondly, it was important to establish that the new measure was able to detect individual differences in prosodic sensitivity. Measures of dispersion indicate that the task was sufficiently sensitive to elicit a range of scores within a typically developing sample of children. It can therefore be posited that the task may be able to detect individual differences in prosodic sensitivity.

It was also necessary to establish that overall task performance on the new measure correlated significantly with reading ability and measures of phonological processing. Partial correlations controlling for vocabulary size and non-verbal IQ confirmed that overall scores on the multi-component measure were correlated with phonological awareness, phonological decoding, text reading accuracy and reading comprehension. These findings replicate results obtained with other measures of word- and phrase-level prosodic sensitivity (e.g., Clin et al., 2009; Goswami et al., 2009; Whalley & Hansen, 2006) and suggest that the task is able to address processes that are related to reading ability.

The final and most important aim of this study was to investigate the extent to which the various elements of prosodic sensitivity, measured at several linguistic levels, in the context of a single task, can be said to reflect distinct underlying skills with independent links to literacy. As a first step towards this goal, the underlying relationships between the different conditions of the multi-component measure were investigated with an exploratory factor analysis. Separate factors comprising word-, phrase-, and sentence-level processing of intonation, word- and phrase-level processing of syllable timing, and word- and phrase-level processing of stress were identified. Overall, this factor structure suggests that the conditions of the task which require different types of prosodic sensitivity—stress, intonation, or timing—are indeed measuring distinct underlying skills. This pattern of factor loadings also suggests that differences in the type of prosodic information manipulated across conditions had a stronger influence on the factor structure than variation in the size of linguistic units. However, it is important to acknowledge that the different types of prosody in this task also required different response formats (e.g., stress: best-fitting answer; intonation: 'asking' or 'telling'; and timing: same-different judgement) and this might provide an alternative explanation of the factor analysis results.

An additional factor comprising sentence-level processing of both stress and timing was also identified. It is possible that this factor is sensitive to differences in short-term memory ability between participants and/or the ability to track stress patterns over a longer timeframe than that of a single word. This is consistent with findings suggesting different roles for word-level and phrase/sentence-level prosodic information in literacy development (Klauda & Guthrie, 2008; Whalley & Hansen, 2006) and it is encouraging to note that the multi-component measure of prosodic sensitivity appears to be discriminating between these skills.

At this stage of measurement development, the relatively small number of trials in each condition of the multi-component task prohibits the use of correlational and group analyses in more detail. However, the future aim is to assess the strength of associations between individual components of the prosodic sensitivity task and measures of literacy ability. Moreover, further work is required to explore the nature of the distinction between stress and syllable timing sensitivity and intonation sensitivity at the sentence-level.

Overall, the findings are in line with previous studies in this area in demonstrating significant associations between prosodic sensitivity and a range of reading ability measures. Moreover, while the newly developed multi-component measure of prosodic sensitivity is not without its problems (e.g., internal reliability was moderate and performance on the component of stress was not above chance) the approach taken has promise in assessing prosodic sensitivity with specific links to language and literacy skills. It offers a way of beginning to explore the complex and interrelated nature of several linguistic skills that have, until recently, been relatively overlooked in reading research.

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Appendix

See Table 4.

Table 4 Stimuli and scoring sheet for the Dina the Diver task

Item 1	Item 2	Stress	Inton.	Timing
Spiderman*(T1, Q2)	Sylvester(S1, D2)	NA	NA	NA
Aladdin*(T)	Tinkerbell(D)			
Pokemon(Q)	Godzilla*(S)			
Dogtanian*(Q)	Scoobydoo(D)			
Backyardigans*(T)	Teletubies(D)			
Bananaman(Q)	Cinderella*(S)			
	Total	/5	/5	/5
Winnie the Pooh(Q1, T2)	Humpty Dumpty*(D1, S2)	NA	NA	NA
Power rangers(Q)	Sesame Street*(S)			
The Jungle Book*(T)	Sleeping Beauty(S)			
Tom and Jerry*(Q)	The Lion King(S)			
My little pony(T)	Beauty and the Beast*(D)			
The three little pigs(T)	Atomic Betty*(D)			
	Total	/5	/5	/5
Pooh got stuck in a hole*(Q1, T2)	Peppa-pig loves to play(D1, S2)	NA	NA	NA
Bugs Bunny likes carrots(T)	Dora loves to explore*(S)			
Noddy lived in toyland*(Q)	Tom likes to chase Jerry(D)			
Tigger jumps in puddles*(T)	Goldilocks likes porridge (D)			
Dumbo had very big ears(Q)	Merlin had a magic wand*(S)			
The wolf tried to eat the pigs*(T)	Barbie was very pretty(S)			

Table 4 continued

Item 1	Item 2	Stress	Inton.	Timing
	Total	/5	/5	/5
	Total across levels	/15	/15	/15
	Overall score		/45	

Stress key: * = correct answer (…items 1 and 2 are used)

Intonation key: (T) = telling, (Q) = question (…items 1 only are used)

Timing key: (S) = same, (D) = different (…items 2 only are used)

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