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Demythifying three orthodox views of cognitive development via functional measurement

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Common sense seems to tell us that young children's cognitive capabilities differ essentially from those of adults. Theories in developmental psychology that are in line with this common-sense idea tend to be readily accepted – even if the data they bring forward are poor, often far away from scientific standards. Like myths that have some plausibility but lack clear, data-based evidence, such theoretical views of cognitive development have been transferred from one generation to the other, almost unquestioned.

The present paper shows how these views can be – and have been – demythified via developmental applications of functional measurement and information integration theory. Here we will concentrate upon three orthodox claims: (1) that young children's cognitive structures are strictly unidimensional and thus not ready for the integration of information, (2) that the holistic mode of information processing has ontogenetic primacy and is the regular one in young childhood, and (3) that cognitive development can best be characterized by a logical sequence of pure conceptual structures.

Myth 1: Young children's cognition is unidimensional

The assertion that young children's cognition is unidimensional up to the age of about 6-7 years goes back to Piaget's (1970) theory of cognitive development and has been maintained in more recent variants (Case, 1992; Siegler, 1998). In its weak version, it states that young children have fundamental limitations in their information processing capacity. In its strong version, it claims that these children consistently focus upon and take into account one information only – which, if true, would of course make the question of information integration irrelevant for this age.

During the past 30 years, developmental applications of information integration theory have found extensive evidence to the contrary. In a vari-

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ety of tasks employing principles of functional measurement, children as young as 5 years of age not only took into account more than one dimension but integrated the information according to meaningful algebraic rules. If a developmental difference between younger children on the one hand and older children and adults on the other hand was found, it usually did not apply to the amount of information that was processed but, rather, to the rule according to which the information was integrated: Particularly in situations in which the normative rule required a non-additive integration, young children occasionally simplified to an additive rule. Both behaviors, needless to say, speak against the myth of unidimensional cognition.

Figure 1 shows just three of many examples. The left panel refers to judgments of rectangle area (Wilkening, 1979). Children were shown chocolate bars, varied in a 4 × 4 factorial width × height design, and had to judge for each bar how long a row of the single pieces would be, if joined together. The data in Figure 1 show the judgments of one individual child, 5 years of age. The graphs for the other children in that age group were essentially similar, and the overall pattern averaged over all 5-year-olds looked even more systematic. Such a pattern of parallelism is a functional measurement sign of an adding rule (see Wilkening, 1979).

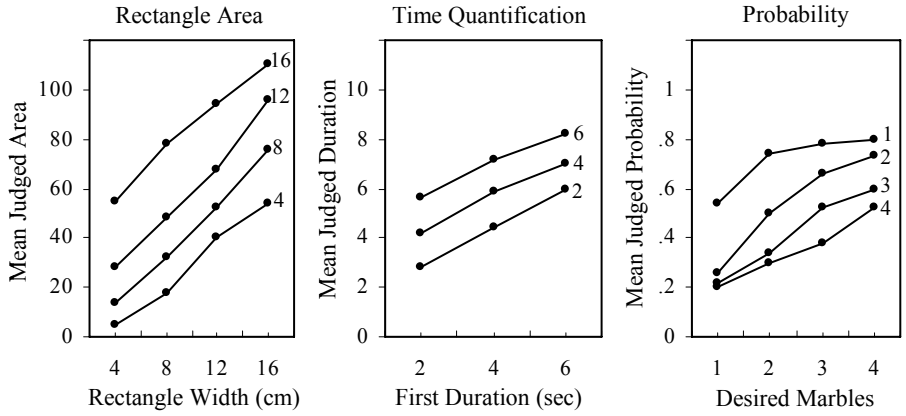

Figure 1. Children's judgment patterns in three different experiments (see text for details). Curve parameters are: Rectangle height in cm (left panel), second duration in sec (center panel), and number of undesired marbles (right panel).

The center panel of Figure 1 shows data from a developmental study on time quantification by Wilkening, Levin, & Druyan (1987). Children of different ages judged the overall duration of two successive events, varied in a factorial design. The mean judgments of the 6-year-olds are presented as an example here. It can clearly be seen that the judgment pattern is in virtually perfect agreement with the parallelism pattern of the adding rule – which is the normative one in this case. There was no sign of *centration*, that is, focusing on one duration and ignoring the other, in any individual child.

The right-hand panel of Figure 1 shows data from a probability experiment by Wilkening and Anderson (1991). Children were shown a plate of marbles, containing 1 to 4 marbles of a desired winning color and 1 to 4 marbles of an undesired color. The task was to judge the degree of happiness over the likelihood of picking a marble with the desired color in a blind draw from the given plate of marbles. In effect, thus, the children had to perform proportional reasoning which, according to Piaget, is impossible below the stage of formal operations, that is, for children younger than about 12 years of age. The data in Figure 1 show the judgments of 8-year-olds. They mirror the slanted barrel pattern for the mathematical correct probability ratio rule almost perfectly. And of course they speak against the myth of unidimensional thinking (see Falk & Wilkening, 1998).

The question arises why the myth of unidimensional thinking could be maintained in light of the many data that have been accumulated in Piagetian and post-Piagetian research. The answer lies in the reliance on the choice-task methodology, which has been employed in those studies, virtually without exception. Choice tasks do not seem to be suited to detect unexpected integration rules (Wilkening & Anderson, 1982). In fact, neither Piaget's theory nor the more modern models developed within the information processing approach have ever considered and tested the possibility of non-normative integration rules, such as the adding rule instead of a normative multiplying one. Indeed, Siegler's (1976, 1998) attempt to incorporate Piaget's choice-task method within an information processing approach not only fails to reveal children's true capabilities but also suffers from "false successes", claiming to see rules that are not there.

Myth 2: Young children are holistic information processors

The assertion that young children's perception and cognition is dominated by a holistic mode of processing can be traced back to the German *Ganzheitspsychologie* of the first half of the past century (e.g., Sander, 1932), and it was taken up in a methodologically more sophisticated

framework in the context of the *separability hypothesis* almost fifty years later (Shepp, 1978; Smith & Kemler, 1978). In its weak version, the idea is that there is developmental trend from a predominantly holistic processing mode in preschool age to a predominantly analytic mode from middle school age up to adulthood. In its strong version, the claim is that young children have no access to the dimensional structure of multidimensional stimuli but perceive them as inseparable, unanalyzable wholes. This claim, if true, would pose some problems with respect to the interpretation of the information integration rules that have been found in young children via functional measurement.

Whereas the data base for the claims of the Ganzheitspsychologie was very weak, if not nonexistent, the data accumulated in support of the separability hypothesis appear impressive at first glance. This research was based on Garner's (1974) distinction between separable and integral stimuli. From the various methods he had proposed as diagnostic tools for obtaining converging evidence of analytic (separable) or holistic (integral) perception in adults, one was deemed suited for the use with young children. This was the restricted classification task: In the prototypical example, the child is shown three squares. Two of them are identical in size, but differ considerably in brightness, one of them (A) appearing as a very light grey, the other one (B) almost black. The third square (C) is a little smaller than A and C and is also different in brightness. On this dimension, however, C is much closer to A, that is, almost as light as A. The assumption is that A and C are closer in overall similarity than A and B since they share an identical value on the dimension of size.

When children in preschool age were asked the critical question, "Which two (of the three) most go together?", the percentage of their classifications by identity (A and B) was found to be not significantly higher than chance, in contrast to the groups of older children and adults, in which the AB-classifications were significantly above chance. The conclusion drawn from such data from many similar experiments was: Young children have no access to the dimensional structure of the stimuli, that is, are unable to see size and brightness as dimensions that can be varied independently from each other. Hence, they cannot see the identity of two stimuli on one dimension but instead group those two together that are most similar overall.

The problems with this conclusion are so obvious (see Wilkening & Lange, 1989, for details) that it remains a mystery why these studies could enter the major developmental journals for more than a decade. One reason might have been that the wrong conclusions drawn from the data were in congruence with the myth of the naturally holistic young child – which seems to be very powerful.

To mention just one problem with the restricted classification paradigm and the interpretations derived from it, consider the possibility that young children's AC-responses were actually based on judging according to "overall similarity" following a city-block metric. This means that children may have added the dissimilarities on both dimensions, size and brightness. Because this sum for A and C was subjectively smaller than the one-dimensional dissimilarity in brightness of the two stimuli identical in size (A and B), the children performed the overall-similarity classification. In Garner's view, which was adopted by the proponents of the separability hypothesis, judgments following a city-block metric are a clear indicator of analytic processing. Thus, children's classification behavior in the cited studies may have been at least as analytic as that of adults.

To test this possibility and to shed more light on the problem, Wilkening and Lange (1989) designed an experiment employing principles of functional measurement, thus enabling a more direct assessment of children's processing mode. Size and brightness were again used as stimulus dimensions, different levels on each characterizing the belly of a dwarf, presented as upright standing ellipses. Two schematic pictures served as end anchors: (a) a dwarf with a thin and light belly and (b) a dwarf with a thick and dark belly. Children were told that the lower end anchor showed how the dwarf normally looks – and that the upper one showed how he looked after he had consumed a bag full of magic candies. For each stimulus of the factorial design, the child's task then was to "guess" how many candies (from a rating scale from 1 to 20) the dwarf might have consumed this time, after he had gotten curious and wanted to try out the effects of other, smaller amounts of candies.

Figure 2 shows the main results, the mean ratings of each of the three age groups investigated in that study. All plots are roughly parallel, with no significant interaction in any group, thus indicating the use of an adding rule over the entire age range from 5 years to adulthood. No developmental trend as to the integration rule can be seen, an impression that was corroborated by analyses of the individual data patterns.

Further analyses carried out by Wilkening and Lange for data they had obtained when applying the restricted classification paradigm to the same stimuli revealed a new problem: The same patterns that in the previous studies would have been interpreted as indicating holistic processing emerged, but they came about through children's focusing on a single dimension – going by identity if there was an identity on that dimension and going by similarity if there was no identity. Such a mix of *centrations* is of course the contrary of what has been described as a holistic mode of processing.

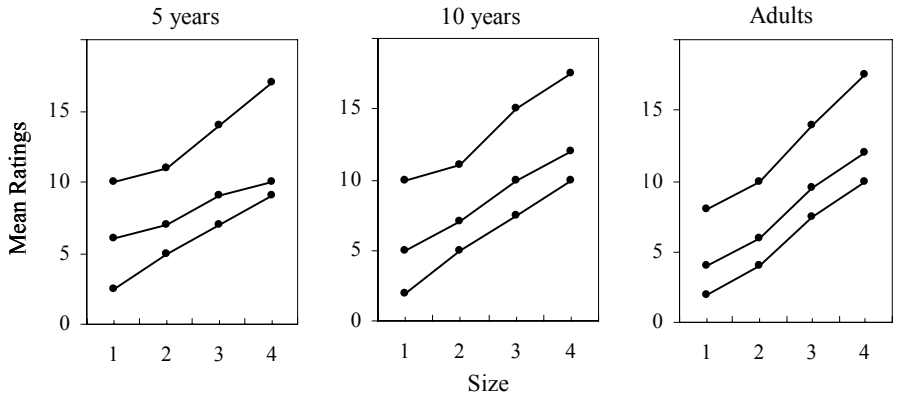

Figure 2. Mean ratings for separable stimuli varying in size and brightness in three different age groups. Curve parameter is Munsell brightness in each panel, with levels of 3, 5, and 7 for the top, middle, and bottom curves, respectively.

It appears, thus, that there is no acceptable evidence for the claim of a developmental trend from holistic to analytic processing, implying that young children have no access to the dimensional structure of stimuli that are separable for adults. The data obtained in developmental applications of functional measurement revealed the contrary: They detected the very rule that the proponents of the separability hypothesis would have required for the assessment of children's analytic processing but were unable to find with their methods. Again, the main problem appears to be located in the choice-task methodology, in this case in the variant of the restricted classification task.

Myth 3: Development follows a logical sequence of pure concepts

For almost a century now, mainstream research in the field of cognitive development has been built upon the assumption, implicitly or explicitly, that the changes occurring in the course of development can be best understood as a logical sequence of conceptual structures, from primitive ones to the highest forms, the endpoints of development being isomorphic to the structure of the outside world. A corollary of the this assumption is the belief that such logical sequences will show up in developmental stud-

ies – provided that the concepts at each stage of development will be revealed and diagnosed in their pure, uncontaminated form. Again, this assertion goes back to Piaget's seminal theory and is often found in the more recent post-Piagetian variants.

In the strong version, the idea of a logical developmental sequence of pure concepts is believed to be true across domains, with only one general sequence, independent of the content area. In the weak version, the belief is thought to be true at least within domains. In any case, a child's knowledge within a domain should be characterized by only one conceptual structure in any phase of development – given that the knowledge is assessed in an adequate way, in tasks freed from all collateral demands.

This traditional line of thought may be illustrated by the question that Albert Einstein had for Jean Piaget: Which concept develops first in children: time or speed? Obviously, the idea behind the question was that a child can have only one time and/or one speed concept at a certain point of development, and that it is the task of the researcher to diagnose that single concept as uncontaminated as possible. Of course, Piaget could easily take up this idea. The answer he presented two decades later, based on several studies employing his choice methodology was: The speed concept comes first in the course of development, years before the time concept emerges. Siegler and Richards (1979), in a modern variant of Piaget's choice methodology derived from the information processing approach, arrived essentially at the same conclusion.

Experiments using functional measurement methodology arrived at dramatically different conclusions about children's concepts of time and speed and their interrelations (Wilkening, 1981). In particular, it was found that the conceptual structures in the different tasks, that is, the integration rules for judging time, speed, and distance, each on the basis of the two other dimensions of that triad, were not at all reversible, in sharp contrast to Piaget's notions.

Even more important, remarkable *knowledge dissociations* appeared in each age group, especially in the young children: If, for instance, the task suggested the use of an eye-movement strategy for integrating the information about time and speed, children as young as 5 years of age produced judgment patterns that were in virtually perfect agreement with the normative multiplying rules. If such a psychomotor action was prevented, the children fell back on adding rules – deviating from the normative rule but still evidencing a much higher knowledge than conceded for this age in Piagetian and information processing theories.

Krist, Fieberg, and Wilkening (1993) elaborated on these findings by investigating children's and adults' intuitive physics about trajectories of

moving objects. In effect, the participants had to estimate the speed a tennis ball had to have as it left the end of an elevated horizontal ramp to hit a target on the floor. Height of the ramp above the floor and horizontal target distance from the ramp were varied in a 4 × 3 factorial design, and the estimates could given either on a speedometer-like rating scale (judgment condition) or by actually producing the speed by pushing the ball on the ramp (action condition). In both conditions, no feedback was given; in the latter, this was prevented by hiding the ball's downward trajectory by a curtain.

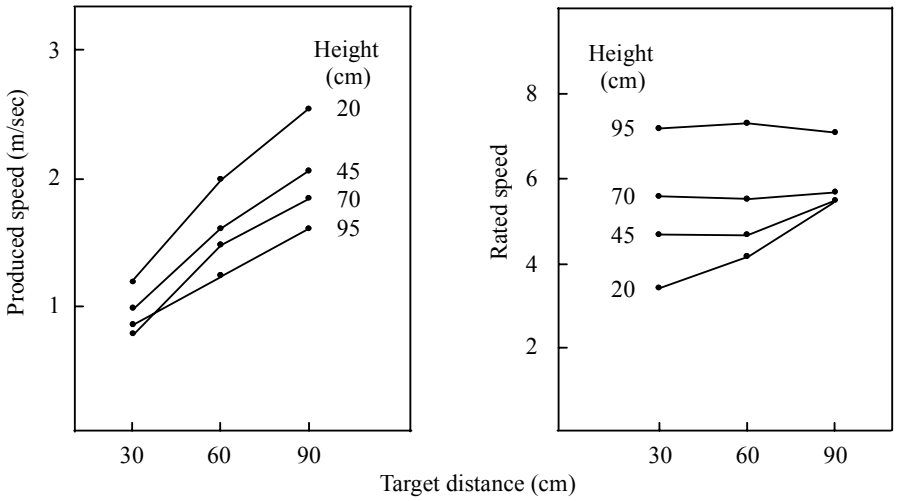

Figure 3. Mean produced speed in the action condition (left panel) and rated speed in the judgment condition (right panel) of a straight throw. The different data patterns shown in both panels stem from the same group of participants, predominantly children, and point to a striking knowledge dissociation.

The judgment and the action condition yielded quite different results. Whereas the data patterns obtained in the action condition were in almost perfect agreement with the normative multiplying rule in all age groups, including children as young as 5 years, this was not generally true for the judgment condition, particularly in the younger groups. Figure 3 shows a comparison of particular interest in the present context. Both data patterns

come from the same subgroup of participants, containing individuals from all age groups, predominantly young children but even some adults. The left panel shows the speed productions, which mirror the physically correct multiplying rule. The right panel shows the speed ratings, which exhibit a dramatically different pattern. Most remarkable is that the levels of the height dimension changed places in the judgment condition: Instead of the correct inverse relation between release height and speed, a direct relation emerged here. These participants appear to have judged according to what can be termed a false height heuristic: The higher the ball's release, the higher the speed. Not one of these individuals acted according to this heuristic when producing the speed with a part of their own body.

These data provide impressive evidence that people, particularly children, can have conceptual knowledge on different levels, at the same time and in the same domain. Analogous findings were obtained in more recent studies by Huber, Krist, and Wilkening (2003) and by Wilkening and Martin (2004). To say which of the different levels, from the implicit embodied forms to the more explicit expressions, represents the pure concept, hardly seems meaningful. Hence, the search for pure concepts, in an attempt to find empirical support for the myth of a logical developmental sequence of conceptual structures, seems seriously misguided. At the same time, it blinds the investigator to the discovery of unexpected rules, such as the false height heuristic.

Conclusion

Certain popular theories of cognitive development are fundamentally inadequate to accomplish their avowed purposes. The root cause of their failure is their inability to deal with problems of information integration. This inadequacy was illustrated with the three foregoing myths and has been further demonstrated in many other experiments on information integration.

Functional measurement theory has been effective in studying information integration by children. It is transparent to the action of the mind. Whatever integration rule a person may use will reveal itself in the pattern of the integration graph. This capability can study individual children instead of obscuring individual differences in faceless group averages.

References

Anderson, N. H., & Wilkening, F. (1991). Adaptive thinking in intuitive physics. In N. H. Anderson (Ed.), *Contributions to information integration theory. Vol 3: Developmental* (pp. 1-42). Hillsdale, NJ: Erlbaum.

Case, R. (1992). *The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge.* Hillsdale, NJ: Erlbaum.

Falk, R., & Wilkening, F. (1998). Children's construction of fair chances: Adjusting probabilities. *Developmental Psychology, 34,* 1340-1357.

Garner, W. R. (1974). *The processing of information and structure.* Hillsdale, NJ: Erlbaum.

Huber, S., Krist, H., & Wilkening, F. (2003). Judgment and action knowledge in speed adjustment tasks: Experiments in a virtual environment. *Developmental Science, 6,* 197-210.

Krist, H., Fieberg, E. L., & Wilkening, F. (1993). Intuitive physics in action and judgment: The development of knowledge about projectile motion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 952-966.

Piaget, J. (1970). Piaget's theory. In P. H. Mussen (Ed.), *Carmichael's manual of child psychology. Vol. 1* (pp. 703-732). New York. Wiley.

Sander, F. (1932). Funktionale Struktur, Erlebnisganzheit und Gestalt. *Archiv für die gesamte Psychologie, 85,* 237-260.

Shepp, B. E. (1978). From perceived similarity to dimensional structure: A new hypothesis about perceptual development. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 135-167). Hillsdale, NJ: Erlbaum.

Siegler, R. S. (1976). Three aspects of cognitive development. *Cognitive Psychology, 8,* 431-520.

Siegler, R. S. (1998). *Children's thinking* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

Siegler, R. S., & Richards, D. D. (1979). Development of time, speed, and distance concepts. *Developmental Psychology, 15,* 288-298.

Smith, L. B., & Kemler, D. G. (1978). Levels of experienced similarity in children and adults. *Cognitive Psychology, 10,* 502-532.

Wilkening, F. (1979). Combining of stimulus dimensions in children's and adults' judgments of area: An information integration analysis. *Developmental Psychology*, *15*, 25-33.

Wilkening, F. (1981). Integrating velocity, time, and distance information: A developmental study. *Cognitive Psychology*, *13*, 231-247.

Wilkening, F., & Anderson, N. H. (1982). Comparison of two rule-assessment methodologies for studying cognitive development and knowledge structure. *Psychological Bulletin*, *92*, 215-237.

Wilkening, F., & Anderson, N. H. (1991). Representation and diagnosis of knowledge structures in developmental psychology. In N. H. Anderson (Ed.), *Contributions to information integration theory. Vol. 3: Developmental* (pp. 45-80). Hillsdale, NJ: Erlbaum.

Wilkening, F., & Lange, K. (1989). When is children's perception holistic? Goals

and styles in processing multidimensional stimuli. In T. Globerson & T. Zelniker (Eds.), *Cognitive development and cognitive style* (pp. 141-171). Norwood, NJ: Ablex.

Wilkening, F., Levin, I., & Druyan, S. (1987). Children's counting strategies for time quantification and integration. *Developmental Psychology*, *23*, 823-831.

Wilkening, F., & Martin, C. (2004). How to speed up to be in time: Action-judgment dissociations in children and adults. *Swiss Journal of Psychology, 63,* 17-29.

Abstract

In traditional accounts of cognitive development, children's cognition is characterized as being (1) initially deficient, confined to unidimensional thinking, (2) holistic, nonanalytic by nature, and (3) governed by strict developmental sequences of conceptual structures. All three accounts are fundamentally incorrect, as developmental applications of functional measurement and information integration theory have shown that children's thinking is multidimensional, analytic, and highly adaptive from the early ages on, with simultaneous knowledge representations at several levels. Children's intuitive physics is a field in which all these capabilities come to light most impressively.

Riassunto

Nei resoconti tradizionali dello sviluppo cognitivo, la cognizione dei bambini è caratterizzata come (1) inizialmente deficitaria, confinata al pensiero unidimensionale, (2) olistica, non analitica per natura, e (3) governata da sequenze evolutive rigide delle strutture concettuali. Tutti e tre questi resoconti sono fondamentalmente sbagliati in quanto le applicazioni della misurazione funzionale e della teoria della integrazione delle informazioni allo sviluppo hanno mostrato che il pensiero dei bambini è multidimensionale, analitico, e altamente adattabile dai primissimi anni in avanti, con rappresentazioni di conoscenza simultanee a diversi livelli. La fisica intuitiva dei bambini è in campo in cui tutte queste capacità vengono alla luce in modo impressionante.

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