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著者	ADACHI Tomoaki, KAWAGOE Soichiro, MURAI Norio
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A Probabilistic Assessment System for ADHD, Learning Disabilities and High-Function Pervasive Developmental Disorder in Early Childhood[1]

Tomoaki ADACHI（足立智昭）[2]
(*Miyagi Gakuin Women's University*)
Soichiro KAWAGOE（川越総一郎）
(*Miyagi Prefectural East Child Guidance Center*)
Norio MURAI（村井憲男）
(*Tohoku University*)

Developmental disabilities such as attention deficit/hyperactivity disorder (ADHD), learning disabilities (LD), and high-function pervasive developmental disorder (HFPDD) have similar clinical properties in early childhood. Consequently, it is very difficult to make an assessment on such disabilities before school age. This study aims to develop a probabilistic assessment system based on the assumption that there is a certain amount of uncertainty in the relationship between clinical properties of children with developmental disabilities and the core problems of these disabilities. The subjects were 32 children with suspected either ADHD, LD, or HFPDD. The system, applying for Dempster-Shafer theory (Shafer, 1976), consists of a knowledge base and an inference engine. The knowledge for predicting ADHD, LD, or HFPDD is stored in the knowledge base as matrices of basic probability data, representing the relation between clinical features in early childhood and these developmental disabilities. The inference engine successively integrates the basic probabilities using Dempster's combination rule. The system computed basic probabilities of ADHD, LD, or HFPDD for each subject (an example subject with HFPDD was assessed as 100% with HFPDD, 38% with ADHD, and 4% with LD). If we used 80% as cutoff point for discrimination of the disabilities, then all subjects but one were classified appropriately. These findings suggest that this system, applying D-S theory, has a high predictive validity and that it can assess co-occurring developmental problems of the developmental disabilities such as ADHD, LD, and HFPDD.

Key words: ADHD, learning disabilities, high-function pervasive developmental disorder, expert system, comorbidity

Introduction

Previous research has indicated that developmental disabilities such as attention deficit/hyperactivity disorder (ADHD), learning disabilities (LD), and high-function pervasive developmental disorder (HFPDD) embrace overlapping problems with cognitive function, affective control, behavior, and learning (Deb & Prasad, 1994; Holtmann, Bolte & Poustka, 2007; Mayes, Calhoun & Crowell, 2000; Seidman et al., 2006; Sturm, Fernell & Gillberg, 2004; Wu,

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2 Correspondence concerning this article should be sent to: Tomoaki Adachi, Department of Developmental and Clinical Studies, Miyagi Gakuin Women's University, 9-1-1, Sakuragaoka, Aoba-ku, Sendai 981-8557, Japan. (E-mail: adachi@mgu.ac.jp)

Anderson & Castiello, 2002). In actuality, in referred clinical samples of children with ADHD, estimates of the prevalence of LD ranged from 10% to 90% (Semrud-Clikeman et al., 1992). Similarly, in children with PDD or autism spectrum disorders (ASDs), estimates of the prevalence of ADHD ranged from 20% to 80% (Lee & Ousley, 2006). As a result, much controversy exits over the diagnostic labels describing these developmental disabilities (O'Brein & Pearson, 2004; van der Gaag, Caplan, van Engeland, Loman, & Builtelaar, 2005). However, analyzing and assessing co-occurring developmental problems is more important to psychologists and teachers for making individual educational programs than for making diagnoses.

This study aims to develop a probabilistic assessment system based on the assumption that there is a certain amount of uncertainty in the relationship between clinical properties of children with developmental disabilities such as ADHD, LD, and HFPDD and the core problems of these disabilities. Although there are several techniques available for treating uncertainties in data and knowledge (Bartels, Thompson & Weber, 1992), this study applies Dempster-Shafer (D-S) theory in the assessment system. The fact that D-S theory may be suited for expert systems in pathology with a limited number of defined disabilities and a limited number of features (van Ginneken & Smeulders, 1991) is the reason it was chosen.

Dempster-Shafer theory, which has been widely used in the field of expert systems as a tool to estimate and integrate uncertain information (Sadiq & Rodriguez, 2005), was proposed by Dempster (1967) and refined by Shafer (1976). This theory proposes useful concepts such as basic probability, lower probability (belief function), upper probability (plausibility), and Dempster's combination rule. For example, if the probability of a factor A predicting ADHD is $P(A)$, the Baysian theory requires the relationship of $P(A) + P(not\ A) = 1$. But Dempster-Shafer theory, which does not have such an imposed restriction, can express the equation of $m(A) + m(not\ A) + m(A, not\ A) = 1$. In this case, $m(A, not\ A)$ means the probability that we cannot judge whether a child is ADHD or not. Therefore the probability of a factor A predicting ADHD is flexibly defined as between $m(A)$ *and* $m(A) + m(A, not\ A)$. In addition to that, if $m1$ and $m2$ are the basic probability inferred from different factors, new and more precise basic probabilities can be obtained by Dempster's combination rule.

Method

Subjects

The subjects were thirty-two children (26 males, 6 females) with suspected either ADHD, LD, or HFPDD born between 1999 and 2003 who were clinically assessed between the ages of 3 and 6 years at Miyagi Prefectural East Child Guidance Center. All children in the study underwent lengthy clinical evaluations including the administration of one or more of the following: the Enjoji Scale of Infant Analytical development (ESID); the Kyoto Scale of Psychological Development 2001; and the WPPSI. The subjects were also received clinical observations of the child during the evaluation; an analysis of semi-structured interviews with parents and teachers; and a review of historical data, including records of screening programs to test infants and younger children, previous evaluations, and the child's developmental history.

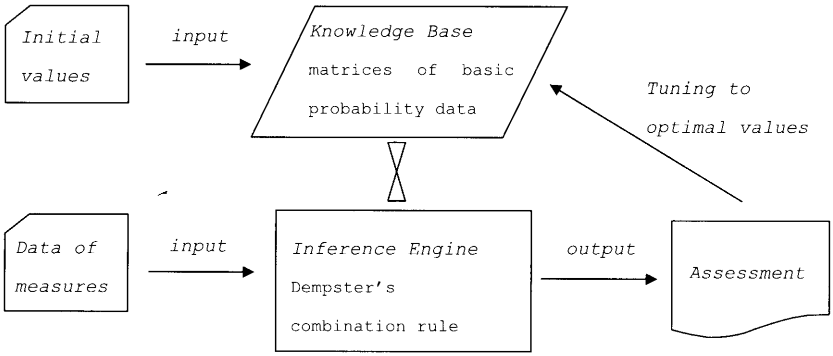

Figure 1. A probabilistic assessment system for applying Dempster-Shafer theory

Diagnoses were based on criteria in the DSM-IV (American Psychiatric Association, 1994) and ICD-10 (World Health Organization, 1993). If a consensus regarding a child's diagnosis was not reached between psychologist and pediatrician, the child was not included in the study.

The system applying Dempster-Shafer theory (Shafer, 1976) consists of a knowledge base and an inference engine (Figure 1.). The knowledge for predicting ADHD, LD or HFPDD is stored in the knowledge base as matrices of basic probability data, representing the relationship between clinical features in early childhood and the developmental disabilities. The inference engine successively integrates the basic probabilities using Dempster's combination rule.

If *m1* and *m2* are basic probabilities inferred from independent evidences, then Dempster's combination rule makes it possible that a new basic probability can be obtained by combining *m1* and *m2* as,

$$m(Ak) = \frac{\sum_{A1i \cap A2j = Ak} m1(A1i)m2(A2j)}{1-\sum_{A1i \cap A2j = \varphi} m1(A1i)m2(A2j))} . \quad (Ak \neq \varphi)$$

Measures and scoring criteria

The system used the following twelve measures and their scoring criteria for probabilistic assessment of developmental disabilities such as ADHD, LD, and HFPDD.

1. Stranger anxiety in infants and toddlers

Stranger anxiety is the distress that young children, from approximately 5 months to 12 months of age, experience when they are exposed to people who are unfamiliar to them. To check, we used maternity passbook, health checkups for infant and 18-month-olds, detailed health checkups for children and information directly from the family.

＋ : If the child didn't show a negative response to strangers, we scored ＋.

± : If the child showed a negative response to only specific stranger or didn't show a clear negative response to strangers with the exception of a brief interval, we scored ±.

− : If the child showed a clear negative response to strangers, we scored −.

2. General developmental delay in first and second years

General developmental delay is defined as significantly subaverage developmental functioning: full DQ of approximately 70 or below on an individually administered DQ test (the Enjoji Scale of Infant Analytical development (ESID), the Kyoto Scale of Psychological Development 2001 or the WPPSI).

+ : If total (or average) DQ was approximately 70 or below, we scored +.

± : If total (or average) DQ ranged from 71 to 80, we scored ±.

− : If total (or average) DQ was above 81, we scored −.

3. Speech developmental delay in first and second years

Speech developmental delay is defined as significantly subaverage speech functioning: verbal DQ of approximately 70 or below on an individually administered DQ test.

+ : If verbal DQ was approximately 70 or below, we scored +.

± : If verbal DQ ranged from 71 to 80, we scored ±.

− : If verbal DQ was above 81, we scored −.

4. Hyperactivity in first and second years

Hyperactivity is defined as excessive moving in home or outside.

+ : If hyperactivity symptoms were observed in two or more settings, we scored +.

± : If hyperactivity tendencies were observed, we scored ±.

− : If the child behaved calmly at a level appropriate for her/his age, we scored −.

5. Perseveration in first and second years

Perseveration is defined as (1) an encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity or focus, (2) an apparently inflexible adherence to specific, nonfunctional routines or rituals or (3) a persistent preoccupation with parts of objects.

+ : If restricted repetitive and stereotyped patterns of behavior, interests, and activities were observed, we scored +.

± : If perseveration tendencies were observed, we scored ±.

− : If the child behaved appropriately for her/his age without strong perseveration, we scored −.

6. Inattention in first and second years

Inattention is defined as (1)failing to give close attention to details, (2)difficulty in sustaining attention in tasks or play activities, (3)failing to listen when spoken to directly, or (4)easy distraction by extraneous stimuli.

+ : If attention-deficit symptoms were observed, we scored +.

± : If attention-deficit tendencies were observed, we scored ±.

− : If the child behaved in concentration appropriately for her/his age, we scored −.

7. Difficulty in emotional regulation in first and second years

Difficulty in emotional regulation is defined as screaming, jumping up and down, rolling around on the floor, hurting oneself, destroying property or attacking others when the child feels discomfort.

+ : If clear difficulties in emotional regulation were observed, we scored +.

± : If such tendencies were observed, we scored ±.

− : If the child behaved appropriately for her/his age when she/he felt discomfort, we scored −.

8. Eye-to-eye gaze difficulty in first and second years

Eye-to-eye gaze is the nonverbal behavior that is used most frequently as a marker of children's interest in interacting with others.

+ : If clear difficulties in eye-to-eye gaze were observed, we scored +.

± : If such tendencies were observed, we scored ±.

− : If the child could meet someone's eyes, we scored −.

9. Intra-individual difference between VIQ and PIQ

Intra-individual difference between VIQ and PIQ is interpreted as an imbalanced development. When we used the Kyoto Scale of Psychological Development 2001, the DQ of the Language-Social Area and the DQ of the Cognitive-Adaptive Area were shown as VIQ and PIQ.

+ : If the difference between VIQ and PIQ was 10 or above, we scored +.

± : If the difference between VIQ and PIQ ranged from 5 to 9, we scored ±.

− : If the difference between VIQ and PIQ was below 5, we scored −.

10. Lack of social or emotional reciprocity with other people

Attachment is considered to be "the strong, affectional tie we feel for special people in our lives that leads us to feel pleasure and joy when we interact with them and to be comforted by their nearness in time of stress" (Berk, 1998). It is commonly believed that children develop social or emotional reciprocity based on their secure attachment base.

+ : If the child could keep quiet when her/his parent wasn't there or didn't develop peer relationships at a level appropriate for her/his age, we scored +.

± : If the child couldn't maintain social interaction with other people (e.g. relating to only parents without others), we scored ±.

− : If the child could relate well to others appropriately for her/his age, we scored −.

11. Trouble in peer relationship

Trouble in peer relationship is defined as punching others, hurting oneself, screaming or destroying property when a child feels discomfort in a group of similarly-aged children.

+ : If the child got into trouble with others frequently, we scored +.

± : If such tendencies were observed, we scored ±.

− : If the child behaved appropriately for her/his age in peer relationships when she/he felt discomfort, we scored −.

12. Hyperactivity in group

Hyperactivity in group is defined as walking around without standing in line, bursting out of a room or talking excessively in a group of similarly-aged children.

+ : If hyperactivity symptoms were observed in groups, we scored +.

± : If hyperactivity tendencies were observed in groups, we scored ±.

− : If the child behaved calmly at a level appropriate for her/his age in groups, we scored −.

Results and Discussion

Basic probability assignment

We supposed that *mA(h1)*, *mA(h2)*, and *mA(h1, h2)* were basic probabilities predicted by a measure of A as ADHD, not ADHD, or both (the same is true in LD and HFPDD). By using this criterion for scoring, we classified the subjects with ADHD into Group +, Group ±, and Group − at each measure. Then, the initial values of the basic probabilities were assigned by the following formulas:

Table 1 A summary of assessment by basic probabilities.

		Basic Probabilities					Basic Probabilities		
Sub.	Diagnosis	LD	HFPDD	ADHD	Sub.	Diagnosis	LD	HFPDD	ADHD
No.1	ADHD	0.07	0.09	1.00	No.17	HFPDD	0.00	1.00	0.74
No.2	ADHD	0.01	0.57	1.00	No.18	LD	1.00	0.03	0.00
No.3	ADHD	0.00	0.14	1.00	No.19	ADHD	0.00	0.09	1.00
No.4	ADHD	0.04	0.14	1.00	No.20	HFPDD	0.02	1.00	0.32
No.5	HFPDD	0.03	1.00	0.00	No.21	HFPDD	0.17	1.00	0.01
No.6	HFPDD	0.00	1.00	0.58	No.22	HFPDD	0.00	1.00	0.00
No.7	HFPDD	0.00	1.00	0.01	No.23	LD&ADHD	0.95	0.11	0.80
No.8	HFPDD	0.00	1.00	0.02	No.24	HFPDD	0.02	0.99	0.00
No.9	LD	1.00	0.01	0.01	No.25	HFPDD	0.06	0.93	0.00
No.10	HFPDD	0.04	0.99	0.00	No.26	ADHD	0.00	0.56	1.00
No.11	HFPDD	0.00	1.00	0.98	No.27	LD	0.95	0.07	0.03
No.12	HFPDD	0.00	1.00	0.00	No.28	ADHD	0.01	0.04	1.00
No.13	HFPDD	0.01	0.93	0.01	No.29	HFPDD	0.38	0.86	0.01
No.14	HFPDD	0.00	1.00	0.11	No.30	HFPDD	0.01	0.95	0.74
No.15	HFPDD	0.00	0.98	0.05	No.31	HFPDD	0.00	1.00	0.10
No.16	ADHD	0.00	0.76	1.00	No.32	HFPDD	0.01	1.00	0.10

* *mA(h1)* = (the number of subjects with ADHD classified into Group + on a measure of A) / (the number of all the subjects with ADHD);
* *mA(h2)* = (the number of subjects with ADHD classified into Group - on a measure of A) / (the number of all the subjects with ADHD);
* *mA(h1, h2)* = (the number of subjects with ADHD classified into Group ± on a measure of A) / (the number of all the subjects with ADHD).

Assessment by basic probabilities

The system computed basic probabilities of ADHD, LD, or HFPDD for each subject as shown in Table 1. If we used 80% as cutoff point for discrimination of the disabilities, then all subjects were classified appropriately, except the case of No.11. However, according to the clinical records, this case showed several hyperactive and impulsive symptoms such as difficulties remaining seated, interrupting others, difficulties waiting for turns and the result of suggesting the possibility of ADHD was not necessarily error. As in the case of No.11, 'comorbidity' of the case of No.23 was appropriately represented by basic probabilities. Consequently, these findings suggest that this system, applying D-S theory, has a high predictive validity and that it can assess co-occurring developmental problems of the developmental disabilities such as ADHD, LD, and HFPDD.

The subject of a further study is to increase the viability of this system applying D-S theory. This can be achieved by examining measures for probabilistic assessment. Future studies should enhance the reliability of measures used in the system not only empirically but also theoretically. At that point, these studies should prove the cross-validity of this system.

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