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Integrative Medicine Research

journal homepage: www.imr-journal.com

Original Article

Temperamental predictors of developmental trajectories of inattention and hyperactivity–impulsivity problems in schoolchildren

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ARTICLE INFO

Article history:
Received 30 August 2016
Received in revised form
17 November 2016
Accepted 18 November 2016
Available online 9 January 2017

Keywords:
hyperactivity–impulsivity
inattention
novelty seeking
persistence
reward dependence

ABSTRACT

Background: The current study aimed to examine the temperamental predictors of developmental trajectory subgroups of children's inattention and hyperactivity–impulsivity problems through a short-term longitudinal study.
Methods: Children (n = 1344) were divided into younger (age 6–8 years) and older (age 9–11 years) groups in order to observe changes in inattention and hyperactivity–impulsivity problems. Inattention and hyperactivity–impulsivity problems were measured three times at 5-month intervals and Cloninger's four temperaments (novelty seeking, harm avoidance, reward dependence, and persistence) were examined on the first occasion only. A cohort sequential design and growth mixture model were used for investigating trajectory subgroups and multiple logistic regression analysis to examine the temperamental predictors.
Results: Developmental trajectories of inattention and hyperactivity–impulsivity showed different subgroupings depending on the age group of children. Temperament (high score on novelty seeking and low score on persistence as well as high score on reward dependence) and gender predicted the likelihood of belonging to high-risk versus low-risk subgroups.
Conclusion: Suggestions taking into account the predictors of developmental trajectories in inattention and hyperactivity–impulsivity problems for future research are discussed along with the limitations of the current study.

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http://dx.doi.org/10.1016/j.imr.2016.11.002

1. Introduction

Since the Attention Deficit/Hyperactivity Disorders (ADHD) is reported to be prevalent in 3–12% of school-age children[1] and 30–50% of the referred cases to psychiatry.[2,3] ADHD has the full attention of many researchers and clinicians.[4] Although ADHD is reported to have three subtypes of Inattention Predominant (I), Hyperactivity–impulsivity predominant (HI), and Combined Predominance (C) in Diagnostic and Statistical Manual of Mental Disorders Fourth Edition, these are not sufficient to cover the heterogeneous characteristics of ADHD in terms of demographics, comorbidity, clinical presentations, response to medication, and prognosis.[5–7] Therefore, it is necessary to identify the developmental homogeneous trajectories or pathways within the heterogeneous ADHD[8] for the better understanding and treatment of them, considering that the diagnostic stability of ADHD is merely up to 50%.[9–11]

While the appearance of statistical methods incorporating developmental changes such as latent growth curve model or general growth mixture model (GGMM) is now possible,[12] several studies have been conducted to investigate the developmental trajectories of problem behaviors,[13,14] but not much regarding ADHD or attention problems including I and HI problems/symptoms.

Simultaneously, children with ADHD are reported to have a certain personality when compared with those without ADHD.[15,16] For example, I is correlated with diligence negatively and with neuroticism positively;[17–19] HI is correlated with compliance negatively and extraversion positively,[20] which were mostly conducted in cross-sectional studies. Therefore, factors that necessitate the potentially different developmental trajectories in ADHD should be examined with longitudinal data. The search for the factors that predict the diverse developmental trajectories of attention problems or ADHD has been of interest to developmental and clinical psychologists as well as child and adolescent psychiatrists.

Considering the importance of the biological contexts in development of attention problems, temperament has been able to be regarded as one of the most studied predictors.[19] Temperament is defined as the individual differences in the adaptation system with regards to the diverse environmental stimuli, and attention problems might be considered as the individual differences in the biological tendency of behavior. As the neurobiological aspects are taken into account due to the higher association between attention problems and biological background, Temperament and Character Inventory (TCI)[21] was chosen to measure this aspect in which many clinicians have shown interest.[22,23]

Children and adults who have ADHD show higher scores on novelty seeking (NS) and lower scores on persistence (PS) and reward dependence (RD) compared with participants in the control group.[24,25] For example, Tillman et al[26] reported that NS was significantly higher and RD and PS were significantly lower in the ADHD group than in the normal control group of early adolescents. The same results were found in Korea among children in both clinical and community samples in mainly cross-sectional studies.[27,28]

In this regard, the current study aimed to investigate the effects of children's temperament on the formation of particular developmental trajectory subgroups of I and HI problems in elementary school children after identifying different subgroups of developmental trajectories. Since the inclusion of preschoolers[29,30] and adolescents[29,31,32] in previous studies hindered researchers from observing minute and fine changes of I and HI problems, the present study focused solely on elementary schoolchildren whose attention problems are known to be more prominent than in other age groups.[5,33]

Furthermore, we divided the sample into two age groups; those above and below age 9 years, in order to catch the more minute changes in problem behaviors based on a review of the literature;[34–36] there is a change of attention problems including I and HI problems around the age of 9 years. In addition, as the majority of studies dealing with clinical samples might not be suitable to be applied to the general development of normal children, the present study used a community sample of elementary school children.

As there is limited literature regarding the predictors of subgroup classification, the results of our study may provide the ideas of predictors contributing to the higher-risk groups of I and HI problems and suggest proper screening and interventions for them in advance.

2. Methods

2.1. *Participants*

Parents of 2287 students in two elementary schools in Gyunggi Province, South Korea, were initially contacted by mail to inform them of the research opportunity after the Department Review Committee of Yonsei University approved the current study in February of 2010. The survey was conducted in three assessment waves during one academic year at 5-month intervals (April 2010, September 2010, and February 2011) with parent-reporting.

The current study was intended to include only cases that had all three measurement results in the analyses for statistical convergence. Additionally, the responses by guardians other than parents and cases with missing responses to >10% of the survey items were excluded in the analyses. Thus, the sample consisted of 1384 children (Table 1). To check for attrition bias, the I and HI scores from the initial pool of participants at the first assessment wave and scores of remaining participants at the third assessment wave were compared. The results suggest that there was a random rather than systematic attrition bias at the third assessment wave ($n = 1384$, $t = 1.8574$, $p = 0.0595$ for I; $t = 1.74$, $p = 0.0821$ for HI).

The sample was then divided into two different age groups—younger ($n = 515$, 6–8 years) and older ($n = 829$, 9–11 years)—based on literature suggesting changes in attention-related problems begin around the age of 9 years.[34–36] Forty 12-year-old students were thus excluded due to their small number as well as for statistical convergence. Therefore, the final data consisted of 1344 participants (674 boys and 670 girls), whose cross-distribution was even ($\chi^2_{(5,\ N\ =\ 1344)} = 10.584$, $p > 0.05$).

2.2. Measurements

2.2.1. Attention problems of children

I and HI were measured with the DuPaul's ADHD Rating Scale (ARS).[37,38] ARS was administered by parents of children and comprised 18 items that measured Diagnostic and Statistical Manual of Mental Disorders Fourth Edition symptoms of ADHD. Each item was scored on a 4-point scale, from 0 (not at all) to 3 (very often), to rate the frequency of the problem behaviors. Nine items measured I and nine items assessed HI. Higher scores reflected more ADHD symptoms. Cronbach α of ARS in the current study was 0.929.

2.2.2. Temperament of children

Temperament of children was measured by the Junior TCI 7–11.[39] The original scale was developed by Cloninger et al.[21] Junior TCI 7–11 was composed of 86 items measuring four temperament dimensions [NS, harm avoidance (HA), RD, and PS] and three character dimensions (self-directedness, cooperativeness, and self-transcendence). The parents were asked to rate their children on a 5-point scale, from 0 (not at all) to 4 (very much so). The higher score the child received, they were rated to be more like the temperament described in the question. The current study used only the four temperament dimensions and the Cronbach α was 0.74–0.82 in the Korean Junior TCI.

2.3. Data analysis

A cohort sequential design, GGMM, and multiple logistics regression analysis were used. As cohort sequential design links adjacent segments of repeated data from different time cohorts to estimate a common developmental trend,[40] each age was taken as a cohort, resulting in the second measurement of the first cohort overlapping with the first measurement of the second cohort. GGMM was used to identify the different subgroups and multiple logistic regression analysis was conducted to examine the effects of temperament in order to explain the differentiation of those subgroups. The variance of the slopes was fixed at zero, assuming no individual differences in the rate of change. Each of the two age groups was analyzed separately. The number of latent classes started with 1. GGMM is useful in identifying different subgroups within a group through a person-oriented approach.[41] GGMM, in particular, classified the latent classes that presented distinct developmental differences. The goodness of fit was used to determine the number of latent classes in GGMM, and its criteria were as follows: (1) the smaller the Bayesian Information Criterion and adjusted Bayesian Information Criterion, the better the model was; (2) the greater the number of latent classes and smaller the Bootstrapped Likelihood Ratio Test *p* value, the number of latent classes was considered valid; (3) the *p* value of the Vuong–Lo–Mendell–Rubin Likelihood Ratio Test or the Lo–Mendell–Rubin Likelihood Ratio Test was used to decide the number of latent classes; (4) the entropy index was used to examine the distinctiveness of latent classes identified, assuming a result >0.8 as good;[41] and (5) theoretical interpretation was used to assess the latent class identification.

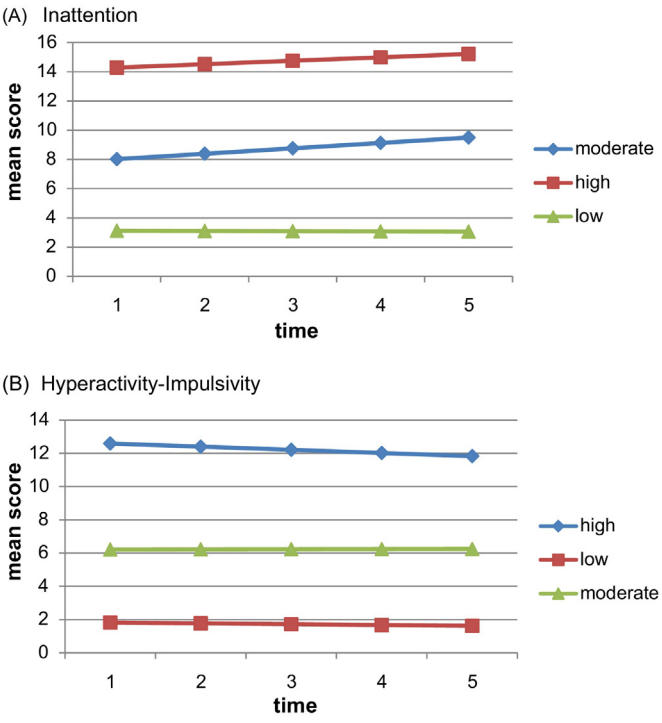

Fig. 1 – Trajectory subgroups of younger children's inattention (A) and hyperactivity–impulsivity (B) problems.

3. Results

3.1. Subgroups and predictors of subgroups in younger children

3.1.1. Subgroups in younger children

Table 2 shows the model comparison results. Three latent classes were identified (Fig. 1A) with respect to I and three latent classes were also identified (Fig. 1B) with respect to HI.

3.1.2. Predictors of Subgroups I and HI problems in younger children

Means and standard deviations (SDs) of the predictors of I and HI subgroups of younger children are shown in Table 3. The multinomial logistic regression analysis yielded a

Table 1 – Distribution of gender and age in participants (*n* = 1384)

	Age 6 y	Age 7 y	Age 8 y	Age 9 y	Age 10 y	Age 11 y	Total
Boys	43 (67.19%)	99 (50.00%)	134 (52.96%)	147 (46.96%)	144 (47.21%)	107 (50.71%)	674 (50.15%)
Girls	21 (32.81%)	99 (50.00%)	119 (47.04%)	166 (53.04%)	161 (52.79%)	104 (49.29%)	670 (49.85%)
Total	64 (4.76%)	198 (14.73%)	253 (18.82%)	313 (23.29%)	305 (22.69%)	211 (15.70%)	1344 (100%)

Table 2 – Fit indices for GGMM of younger children's inattention and hyperactivity–impulsivity

	BIC	adj. BIC	BLRT *p*	VLMR *p*	LMR *p*	Entropy
Inattention						
1-trajectory model	9556.435	9534.216	N/A	N/A	N/A	N/A
2-trajectory model	9002.810	8971.069	0.0000	0.0000	0.0000	0.843
3-trajectory model	8902.173	8860.909	0.0000	0.0004	0.0006	0.810
4-trajectory model	8898.378	8847.591	0.0000	0.5449	0.5594	0.714
5-trajectory model	8903.378	8843.069	0.0000	0.4580	0.4652	0.715
Hyperactivity–impulsivity						
1-trajectory model	9117.716	9095.497	N/A	N/A	N/A	N/A
2-trajectory model	8593.242	8561.500	0.0000	0.0000	0.0000	0.860
3-trajectory model	8470.651	8429.387	0.0000	0.0007	0.0010	0.814
4-trajectory model	8437.792	8387.005	0.0000	0.2444	0.2605	0.783
5-trajectory model	8423.692	8363.382	0.0000	0.3038	0.3138	0.809

adj., adjusted; BIC, Bayesian Information Criterion; BLRT, Bootstrapped Likelihood Ratio Test; GGMM, general growth mixture model; LMR, Lo–Mendell–Rubin Likelihood Ratio Test; N/A, not applicable; VLMR, Vuong-Lo-Mendell-Rubin Likelihood Ratio Test.

significant result ($\chi^2 = 218.174$, $p < 0.001$; $\chi^2 = 149.270$, $p < 0.001$), respectively, in I and HI subgroups. This means that the higher the NS and lower the PS, the probability of belonging to a high I/HI group, rather than moderate I/HI group, increased.

3.2. *Subgroups and predictors of subgroups in older children*

3.2.1. *Subgroups in older children*

Table 4 shows the model comparison results. Five latent classes were identified (Fig. 2A) with respect to I and four latent classes were identified (Fig. 2B) with respect to HI.

3.2.2. *Predictors of Subgroup I problems in older children*

Means and SDs of the predictors of Subgroups I of older children are shown in Table 5. The multinomial logistic regression analysis yielded a significant result ($\chi^2 = 440.124$, $p < 0.001$). Specific results are as below. First, the distinguishing factors for low stable and high stable I groups were NS [$B = 0.144$, standard error (SE) = 0.018, Wald = 62.619, $p < 0.001$], RD ($B = 0.056$, SE = 0.022, Wald = 6.798, $p < 0.01$), and PS ($B = -0.245$, SE = 0.024, Wald = 108.491, $p < 0.001$). Second, the distinguishing factors for low stable and very high stable I groups were sex ($B = 0.1.644$, SE = 0.436, Wald = 14.216, $p < 0.001$), NS ($B = 0.196$, SE = 0.028, Wald = 49.639, $p < 0.001$), HA ($B = 0.058$, SE = 0.025, Wald = 5.513, $p < 0.05$), RD ($B = 0.124$, SE = 0.034, Wald = 13.397, $p < 0.001$), and PS ($B = -0.442$, SE = 0.044, Wald = 101.896, $p < 0.001$). Third, the distinguishing factors for low stable and

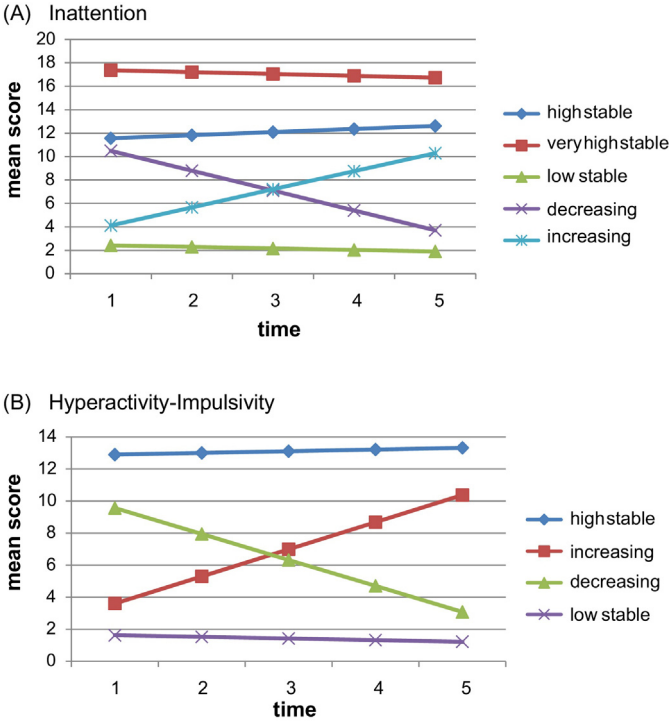

Fig. 2 – Trajectory subgroups of older children's inattention (A) and hyperactivity–impulsivity (B) problems.

Table 3 – Means and standard deviations of trajectory subgroups of younger children's inattention and hyperactivity–impulsivity

	Trajectories (*n*)	Sex	Temperament			
		Boys (%)	NS	HA	RD	PS
Inattention	Low (276)	125 (45.3%)	16.32 (6.96)	18.40 (7.92)	29.62 (6.86)	28.32 (6.64)
	Moderate (175)	112 (64.0%)	19.54 (6.72)	19.86 (7.75)	29.90 (6.00)	24.10 (5.61)
	High (64)	39 (60.9%)	24.09 (7.15)	21.20 (7.58)	30.38 (5.61)	19.38 (5.45)
Hyperactivity–impulsivity	Low (289)	135 (46.7%)	15.88 (6.64)	18.53 (7.98)	29.49 (6.75)	27.11 (7.01)
	Moderate (160)	95 (59.4%)	20.23 (6.78)	19.95 (7.94)	30.05 (5.99)	25.04 (6.24)
	High (66)	46 (69.7%)	24.83 (6.54)	20.68 (6.87)	30.61 (5.97)	21.74 (6.05)

HA, harm avoidance; NS, novelty seeking; PS, persistence; RD, reward dependence.

Table 4 – Fit indices for GGMM of older children's inattention and hyperactivity–impulsivity

	BIC	adj. BIC	BLRT	VLMR	LMR	Entropy
Inattention						
1-trajectory model	15586.183	15563.954	N/A	N/A	N/A	N/A
2-trajectory model	14493.789	14462.032	0.0000	0.0000	0.0000	0.868
3-trajectory model	14228.238	14186.955	0.0000	0.0000	0.0000	0.859
4-trajectory model	14202.405	14151.595	0.0000	0.0401	0.0456	0.806
5-trajectory model	14169.459	14109.121	0.0000	0.0107	0.0130	0.759
6-trajectory model	14172.411	14102.547	0.0128	0.0819	0.0893	0.750
7-trajectory model	14181.692	14102.300	0.0000	0.1370	0.1432	0.756
Hyperactiviy–impulsivity						
1-trajectory model	14318.130	14295.901	N/A	N/A	N/A	N/A
2-trajectory model	13361.072	13329.316	0.0000	0.0000	0.0000	0.899
3-trajectory model	13161.409	13120.125	0.0000	0.0271	0.0310	0.869
4-trajectory model	13086.017	13035.206	0.0000	0.1763	0.1869	0.838
5-trajectory model	13034.400	12974.063	0.0000	0.0592	0.0658	0.801
6-trajectory model	13026.703	12956.838	0.0000	0.7893	0.7939	0.832
7-trajectory model	13013.686	12934.295	0.0000	0.6138	0.6202	0.822

adj., adjusted; BIC, Bayesian Information Criterion; BLRT, Bootstrapped Likelihood Ratio Test; GGMM, general growth mixture model; LMR, Lo–Mendell–Rubin Likelihood Ratio Test; N/A, not applicable; VLMR, Vuong-Lo-Mendell-Rubin Likelihood Ratio Test.

Table 5 – Means and standard deviations of trajectory subgroups of older children's inattention and hyperactivity–impulsivity

	Trajectories (*n*)	Sex	Temperament			
		Boys (%)	NS	HA	RD	PS
Inattention	Low stable (405)	158 (39.01%)	15.00 (6.79)	17.47 (8.02)	29.25 (6.23)	28.00 (6.23)
	Increasing (105)	52 (49.52%)	17.06 (7.00)	19.12 (8.58)	29.57 (6.59)	24.64 (6.13)
	Decreasing (126)	74 (58.73%)	19.93 (6.87)	20.88 (7.46)	28.13 (6.18)	22.46 (5.89)
	High stable (144)	75 (52.10%)	21.18 (7.46)	20.14 (7.35)	28.59 (6.56)	21.11 (5.81)
	Very high stable (49)	39 (79.59%)	24.16 (7.63)	20.96 (8.81)	28.86 (7.03)	16.88 (5.34)
Hyperactivity–impulsivity	Low stable (551)	222 (40.29%)	15.37 (6.64)	18.03 (8.11)	29.05 (6.25)	25.97 (6.92)
	Increasing (82)	50 (60.98%)	19.02 (6.58)	18.81 (7.27)	30.22 (5.77)	24.47 (6.03)
	Decreasing (147)	90 (61.22%)	21.96 (7.06)	21.16 (7.85)	27.57 (6.70)	22.05 (6.64)
	High stable (49)	38 (73.47%)	27.57 (6.65)	21.39 (7.76)	30.39 (7.14)	21.84 (6.35)

HA, harm avoidance; NS, novelty seeking; PS, persistence; RD, reward dependence.

increasing I groups were NS ($B = 0.042$, SE = 0.018, Wald = 5.347, $p < 0.05$), RD ($B = 0.064$, SE = 0.022, Wald = 8.702, $p < 0.01$), and PS ($B = -0.121$, SE = 0.022, Wald = 31.699, $p < 0.001$). Fourth, the distinguishing factor for high stable and decreasing I groups was PS ($B = -0.058$, SE = 0.024, Wald = 5.879, $p < 0.05$).

This means that higher the NS and RD, and lower the PS, the probability of belonging to high stable I group, rather than low stable I group, increased and that for boys, the higher the NS, HA and RD, and lower the PS, the probability of belonging to very high stable I group, rather than low stable I group, increased.

3.2.3. *Predictors of Subgroup HI problems in older children*

Means and SDs of the predictors of HI subgroups of older children are shown in Table 5. The multinomial logistic regression analysis yielded a significant result ($\chi^2 = 280.686$, $p < 0.001$). Specific results are as below. First, the distinguishing factors for low stable and high stable HI groups were gender ($B = 1.268$, SE = 0.384, Wald = 10.884, $p < 0.01$), NS ($B = 0.241$, SE = 0.028, Wald = 76.050, $p < 0.001$), and PS ($B = -0.112$, SE = 0.028, Wald = 15.572, $p < 0.001$). Thus for boys, higher the NS, and lower the PS, the probability of belonging to high stable HI group, rather than low stable HI group, increased. Second, the distinguishing factors for low stable and increasing HI groups were gender ($B = 0.849$, SE = 0.258, Wald = 10.823, $p < 0.01$), NS ($B = 0.067$, SE = 0.019, Wald = 12.099, $p < 0.01$), RD ($B = 0.046$, SE = 0.023, Wald = 4.091, $p < 0.05$), and PS ($B = -0.045$, SE = 0.020, Wald = 5.158, $p < 0.05$). In other words, higher the NS and RD, and lower the PS, the probability of belonging to increasing HI group, rather than low stable HI group, increased in boys. Third, the distinguishing factors for high stable and decreasing HI groups were NS ($B = 0.095$, SE = 0.026, Wald = 12.993, $p < 0.001$). This means that higher the NS, the probability of belonging to high stable HI group, rather than decreasing HI group, increased.

4. Discussion

This study aimed to answer the question regarding the temperamental predictors of developmental trajectories after identified the subgroups of developmental trajectories of with I and HI problems in elementary schoolchildren. Based on a review of the literature,[34–36] we divided the sample into two age groups, those above and below age 9 years, in order to catch the more minute changes in problem behaviors.

The developmental changes in I and HI over a course of time were diverse: three subgroups were identified for both I and HI, with low, moderate, and high stable trajectories in the younger children; while five subgroups were identified for I (low stable, increasing, decreasing, high stable, and very high stable trajectories) and four subgroups for HI (low stable, increasing, decreasing, and high stable trajectories) in the older children.

With regards to temperament, NS was shown to be positively related with I and HI problems and PS negatively, which is consistent with extant literature.[42,43] That is, both higher NS and lower PS are dominant factors in predicting high risk (e.g., high, very high trajectories) from low-risk subgroups (e.g., low, decreasing trajectories) in both I and HI problems of younger and older children.

RD was found to be positively related to I and HI problems, which was contrary to the literature that explains that it is negatively related to ADHD.[44,45] It is possible that those who desire reward and social approval may seek to form relationships with others and be sensitive to what others say, act, and respond to their behaviors. This might drive the children to be less attentive to certain activity goals and distract them toward social interaction only. Considering that the current literature is predominantly based on the comparison studies between clinical and community samples or between ADHD subtypes,[24,27] more studies with community samples are required to clarify this relation.

As for HA, it only distinguished low stable from very high stable I subgroups in older children. Generally speaking, HA is positively associated with internalizing problems such as social anxiety disorder, specific phobia, and depression.[46,47] High rates of ADHD comorbidity with internalizing problems ranging from 27% (depressive disorders) to 51% (anxiety disorders) have been reported in schoolchildren,[7] which suggests that higher HA is positively associated with increased comorbidity of ADHD symptoms. Future studies should examine the association between HA and attention problems with or without comorbid problems in the context of developmental trajectories.

Furthermore, the effects of sex were examined in relation to the diverse trajectory subgroups I and HI of ADHD. Boys were more likely to be found in moderate and high than low I/HI trajectory subgroups of younger children as well as in increasing HI trajectory subgroups of older children. This supports the literature that found more boys with ADHD than girls with ADHD.[48,49] In high stable and very high stable trajectory subgroups of inattention in older children, boys accounted for 52.1% and 79.59% of the group, respectively, which is consistent with Gaub and Carlson's[50] finding that male to female ratio difference in clinical samples is greater than those in community samples. In other words, being boys play an important role in beloning to high-risk (e.g., very high stable subgroup) versus low-risk subgroups in younger and older children.

To summarize, this study followed the developmental trajectories of I and HI problems over three different time points, particularly considering there are few existing studies which examined I and HI problems separately. The current findings showed that the results of western countries can be replicated in samples of eastern countries such as Korea. Furthermore, the biggest contribution this study makes to the current literature is that the investigation of subgroups of attentional problems with their predictors, which has not been examined in depth.[4]

Most importantly, this study might provide implications for intervention. With the knowledge on factors that facilitate or prevent attention problems, the preventative intervention becomes feasible. For the children who show high NS and low PS, for example, effective prevention programs that promote their assets and hinder the development of attention problems can be carried out. Also, a parent education program that helps parents be more effective in parenting the children with certain risk factors of temperament may be viable.[23]

The following limitations and suggestions are made for future research. First of all, even though this study used a cohort sequential design with three surveys administered at 5-month intervals over a period of almost a year, it provides limited scope in looking at children's development. Therefore, in order to generalize the findings of this study, a longitudinal study that covers a longer period of time is necessary. Second, this study analyzed only cases in which responses were provided for all three points of measurement. Even though this helped increase the accuracy of statistical models, the possibility that the attrition may have been systematic still remains. This possibility not only forces attention to be paid to the generalizability of the findings of this study, but also points to the need to develop a proper method to take potential systematic attrition into account. Third, only the biological predictor temperament was investigated in the present study. The role of environmental predictors such as parenting, which can predict the bifurcation of inattention and hyperactivity problems, should be investigated in the attempt to understand the development of inattention problems and hyperactivity problems in future studies. Last, both inattention/hyperactivity problems and temperament traits were obtained only by the children's parent, resulting in the lack of independent measurement and/or artifact relations between them. Therefore, independent measure of child behavioral problems or temperament traits should be assessed in the future study.

The present findings confirmed compatible characteristics with studies of western cultures[30,36,51] regarding subgroups in developmental trajectories despite the social, economic, and cultural differences. Since there has been a scarcity of studies dividing attention difficulties into I and HI problems to observe the developmental trajectories in this age group, further studies should be conducted to corroborate the current findings.

Conflicts of interest

The authors have no financial conflicts of interest.

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