A Longitudinal Study of Twins in Early Childhood

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"Which determines children's physical and mental development, genes or environment?"

This old question has been a big concern for all the people who work for child rearing. There are two issues in this way of asking. First, this is an either-or question, and second, this uses the word "determine". Although it has been long since "interaction between genes and environment" became common in textbooks of psychology, even experts still often tend to take sides, arguing "it is genes that determine…." , or "No, it is due to environment." If parenting and educational policies are designed under this naïve, over-simplified view, appropriate preparation of nurturing environment would be neglected and inappropriate educational treatments would be provided to children by blind nurture myth.

Why do these things happen? It is because it has not been shown how genetic and environmental factors actually work in children's physical growth and mental development. Only a longitudinal study by the twin method can clarify this question. A similarity comparison between monozygotic (MZ; identical) twins who share 100 % genes and dizygotic (DZ; fraternal) twins who share only 50 % genes with the same environment as MZs'provides information about genetic effects, common environmental effects shared by family members (shared environment), and non-shared environmental effects unique to each of family members on development. Furthermore, by collecting long-term systematic data of twins'development, we can understand how genetic and environmental effects change and how environmental factor alter genetic expression in the process of development.

"Tokyo Twin Cohort Project (ToTCoP)" has been conducting a longitudinal study with over 1,600 pairs of infant twins for four and a half years since 2005. This is not only the biggest twin study but also an incomparable one as longitudinal cohort study in infancy and early childhood in Japan. So far, this project has revealed the three findings as main results.

1. Genetic and environmental effects change in developmental process.
2. Genes and environment interact with each other.
3. There are environmental effects independent of genetic effects.

In the following sections, these three kinds of findings will be introduced, focusing on sociality, an important aspect of human development.

1. Genetic and environmental effects change in developmental process.

"Heredity" tends to be interpreted as fixed stuff such as "predetermined" and "hard-wired" factor. Our longitudinal twin study, however, revealed that both genetic and environmental effects show dynamic changes during infancy and early childhood.

For example, genetic contribution to social behaviors such as pointing and joint attention (measured by M-CHAT, an early screening scale for autism) was very small (13%) at 11 months of age, and shared environment explained the most (78%). However, genetic effects drastically increased up to 58 to 94% at 18 months of age due to new genetic expression which did not emerge at 11 months. For cognitive ability measured by the Bayley Scales of Infant Development, genetic effect which was not identified at 12 mo. was found at 18 mo. This increasing tendency of genetic influence by novel genetic expression was also found in body size growth such as height, weight, chest and head circumferences, in which absolute genetic variances are larger in several months after birth than at birth.

A naïve intuition tells that genetic characteristics with no environmental effects appear at birth and environmental influences gradually change these characteristics as children grow. Our longitudinal twin study drew, however, the completely opposite picture. Children at birth are strongly affected by uterine environment where fetuses were "incarcerated" and, therefore, shared environment explains most part of individual differences, whereas after birth, when children become autonomous outside uterus and start their own life, developmentally-sensitive genetic factors are "switched on" and it seems that they try to "become themselves", because specific combination of one's genes is his/her unique starting point.

Genetic influences on body sizes once decrease from 10 to 12 month and shared environmental influence increases instead. This periodis the transitional phase when infants'locomotion changes from crawling to upright walking. At the same time, this period is the point when social cognition such as joint attention develops as is called "9 month revolution". Our finding suggests that such physical and mental changes are affected by quality and quantity of parental supports and physical conditions at home.

It is known that children with autism, which is developmental malfunction in social cognition sometimes show faster growth in their head circumference (HC) in the first year of life (Courchesne et al., 2004). How do genes and/or environment bridges between body and mind in this kind of sociality? Significant genetic correlation was found between growth rate of HC from birth to around 10 months old and autistic traits measured by M-CHAT) at 18 months old. This genetic correlation was greater in boys (−.62) than in girls (−.49), which showed that the faster HC grows genetically the more autistic infant become genetically. Interestingly, shared and non-shared environments work completely in the opposite direction; environmental influence which facilitates growth rate in HC

dampens autistic traits for both boys and girls. This result suggests an interesting working hypothesis for emerging process of autism that environmental factors may usually buffer rapid growth of HC by genetic factor and that the imbalance of genetic and environmental influences of HC growth and autistic traits leads to autism.

2. Genes and environment interact with each other.

Genetic factors change their appearance depending on environmental factors. Or environmental factors alter their effects according to genetic factors. These are called gene x environment (GE) interaction. How does GE interaction appear in development of sociality in early childhood?

We investigated the relationship between parenting and children's developmental changes of "emotional problem", an aspect of problem behaviors measured by the Strength and Difficulty Questionnaire (SDQ), from 36 to 48 months of age. Result showed that negative parenting (NP) such as harsh discipline, low levels of parental warmth, and physical and psychological control enlarge genetic variance of emotional problem and positive parenting diminishes genetic individual difference, which reminds of a famous introduction of Anna Karenina (L. Tolstoy), "Happy families are all alike; every unhappy family is unhappy in its own way". This suggests that harsh discipline is not necessarily effective for children with some genetic tendencies (eg. very shy or highly nervous).

Previous research has suggested that relationship between children's conduct problems (CP) and negative parenting is mediated by children's hyperactive-impulsive-attention (HIAT). That is, children with HIAT tend to be strictly disciplined and then lead to CP. However, it might be possible to imagine that genetically problematic children tend to be disciplined strictly regardless of children's tendency of HIAT. Our investigation for parents of twins in early childhood (mean age was 6.72 years old) revealed causal relationship between NP and CP (measured by SDQ) mediated by HIAT. Results indicated that, for genetically low HIAT children, genetic tendency of CP elicited NP, whereas, for genetically high HIAT, NP as shared environment elicited CP.

Thus, genetic and environmental influences on development are basically very complicated. They differ for different kinds of behaviors, environmental conditions, genders, developmental stages and, above all, for individuals with different genetic predispositions. We should realize the risk that child-care policies and educational designs become unrealistic, if we don't take into account genetic effects according to simple naïve nurture myth.

3. There are environmental effects independent of genetic effects.

Twin study can, however, also show that environment has its own educational effects independent from genetic effects by controlling genetic factors.

For example, cognitive ability at 24 months of age becomes higher if parents read

books to their children when they are 18 months. Although this relationship is, in part, due to genetic factors; that is, genetically bright children tend to elicit parents reading, direct environmental effects were also found even after controlling this genetic effect. The same kind of causal relationship was found between parents'liberal attitude toward children such as "not to force children to do what children don't want to do" and "let children do as they like" when twins were 15 months of age and cognitive abilities at 18 and 24 months of age. These are mainly shared environmental influences, this means that by giving them from parents actively, they have a same effect for both very similar MZ siblings and DZ with different characteristics in the same way actively by their parents.

Shared environmental influence was also dominant in Kana reading ability at 42 months of age. Although Kana-related abilities such as working memory, vocabulary, and general cognitive ability showed genetic components, relationships between Kana ability and these Kana-related abilities were mediated by shared environment. These results suggest that it is important to prepare opportunities to learn Kana intentionally and unintentionally at home. Dominance of early environment for linguistic activity was also shown in brain activity in mother language cognition at 6 to 10 months of age measured by Near Infrared Spectroscopy (NIRS). There was no genetic effect on oxyhemoglobin change in both hemispheres while infants are listening to mother language utterance, and only shared and non-shared environment affect these changes. .

Causal relationships between parenting behaviors (PB) and children's CP at 42 and 48 months of age were investigated. Results indicated pure environmental effects controlled by genetic effects showed both in simultaneous (eg. PB at 48 mo. affect CP at 48 mo., or CP at 48 mo. affect PB at 48 mo.) and time-lagged (eg. PB at 42 mo. affect CP at 48 mo., or CP at 42 mo. affect PB at 48 mo.) ways for different kinds of PB and CP.

Our project concretely revealed that it is impossible to answer "either genetic or environmental" question in human physical and psychological development. Relationships between gene and environment are diversified, dynamic and complicated. Although our findings have practical implications for nurturing and education, they might be like "blind men and an elephant" story in front of these complexities. Therefore, we have to avoid simple generalization and to be brave to accept these complexities as they are. Our findings would be different for different ages, cultures and societies.

However, knowing that genetic and environmental factors show dynamic changes, interact with each other, and that independent environmental contribution affect children's development will provide us scientific evidence for the design of educational settings for children's healthy development.