Stability and change in genetic and environmental components of personality in old age

Sanna Read a,*, George P. Vogler b, Nancy L. Pedersen c,d, Boo Johansson e,a

a Institute of Gerontology, University College of Health Sciences, P.O. Box 10226, 551 11 Jönköping, Sweden
b Department of Biobehavioral Health and Center for Developmental and Health Genetics, The Pennsylvania State University, University Park, United States
c Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden
d Department of Psychology, University of Southern California, Los Angeles, CA, United States
e Department of Psychology, University of Gothenburg, Sweden

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Abstract

Stability and change in the mean levels and sources of variation in personality was examined. A sample of 149 monozygotic and 202 dizygotic twin pairs over 80 years were studied three times with a 2-year interval between measurement occasions. The Eysenck Personality Inventory to measure extraversion and neuroticism was used. Linear mixed models and Cholesky variance decomposition were carried out (age, gender and mortality controlled). High mean level stability was found in extraversion and neuroticism. Mortality was related to lower scores in extraversion and higher scores in neuroticism. In extraversion and neuroticism, genetic effects were moderate. Though no new genetic contributions emerged over time, significant new environmental effects were found over time. Controlling for mortality slightly increased genetic effect in extraversion.

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* Corresponding author. Tel./fax: +44 20 8942 5996 (U.K.).
E-mail address: sanna.read@hhj.hj.se (S. Read).

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1. Introduction

Issues regarding genetic and environmental sources of individual differences, their stability, and their importance for phenotypic stability and change are pertinent to psychology. These issues can be addressed by decomposing the phenotypic variance into genetic and environmental components and comparing the effects of these components on personality cross-sectionally in different age groups or longitudinally over time. Though stability and change of personality traits over time in adulthood has received substantial attention in gerontology in old age development (Roberts & DelVecchio, 2000), its sources of individual variance has been studied less. The stability of genetic and environmental effects over time becomes an interesting question, especially, as closeness to death may challenge the generalizations concerning stability in personality traits in old age.

Personality traits are mostly consistent in adulthood and old age. Stability is found both in mean levels and test–retest correlations in older people (Kogan, 1990; Martin, Lang, & Poon, 2002; Nilsson, 1983; Pedersen & Reynolds, 1998). Test–retest correlations even increase with age. In their recent review, Caspi, Roberts, and Shiner (2005) described the stability and change in personality in adulthood by three principles: (1) The maturity principle means that most people develop traits (such as becoming more dominant, agreeable, conscientious and emotionally stable) over time, which is positively correlated with personality growth and being a productive and involved contributor to society. (2) Cumulative continuity principle refers to that stability in personality attributable to genetic factors. Environmental influence may produce short-term changes, but genetic factors contribute to individual set points to which individuals return. People create, seek out and end up in environments that are correlated with their traits. Stability can also result in the process of developing, committing to and maintaining an identity. Moreover, normative developmental changes in personality may contribute to increasing personality continuity with time, e.g. such traits as agreeableness, conscientiousness, and emotional stability are positively correlated with personality consistency. (3) The corresponding principle indicates that within personality development continuity and change coexist. For instance life experiences deepen the characteristics that lead people to those experiences in the first place.

Stability and change in personality has also to be considered in terms of study methods and characteristics of the sample. A longer time interval between the measurement points may result in increased instability of personality scores (Kogan, 1990). Latent growth curve models have indicated that even though the mean level is stable, there are individual differences in personality change in old age (Helson, Kwan, John, & Jones, 2002; Mroczek & Spiro, 2003; Small, Hertzog, Hultsch, & Dixon, 2003). Personality appears to become less stable in very old age and close to death (Berg, 1996; Martin et al., 2002; Pedersen & Reynolds, 1998). Survival has been shown to be related to, for instance, higher extraversion and lower neuroticism scores (Nilsson, 1983; Pedersen & Reynolds, 1998; Wilson, Mendes de Leon, Bienias, Evans, & Bennett, 2004). Thus, mortality may affect both mean levels and variances in normally stable personality traits.

Personality is moderately heritable (about 40–60%) and the greatest sources of individual differences during adulthood are non-shared environmental influences (see for a review Bouchard & Loehlin, 2001). Studies on genetic stability and change in older age using longitudinal data are very few in number. Viken, Rose, Kaprio, and Koskenvuo (1994) carried out a 6-year follow-up of personality among the twins between 18 and 59 years of age. They found that genetic influ-
ences were shared across the time points, but environmental influence was less stable as new environmental influences are activated. Pedersen and Reynolds (1998) found similar results in a 10-year follow-up of twins aged between 26 and 97. Moreover, they found that the relative importance of genetic influences for neuroticism decreased during the follow-up. For extraversion, the contribution of genetic components remained stable across the four measurement points. In the Minnesota Twin Study, personality was studied using the Multidimensional Personality Questionnaire (MPQ) measuring 11 personality dimensions (Johnson, McGue, & Krueger, 2005). A sample of approximately 59 years old twins participated to the baseline and a follow-up about 5 years later. In congruence with the studies mentioned above, the results indicated high stability in genetic effects over the follow-up period, but also considerable stability of environmental factors.

These studies mentioned above indicate a high level stability in genetic, and also to some extent in environmental factors in personality. However, none of the previous studies have focused on very old people. In very old age, personality may become less stable and the closeness of death may influence the results. The present study is the first to have twins over 80 years of age and modeling mortality in the component estimation to see if it has influence on the stability of genetic and environmental factors. Stability and change of mean levels and genetic and environmental influences on individual differences over time for extraversion and neuroticism (Eysenck & Eysenck, 1975) were tested. On the basis of the previous research findings from adult populations, we expected considerable stability in mean levels. The contribution of genetic effects to phenotypic stability was expected to be the same across time, whereas environmental influence would change over time. The total variance in personality should be explained largely by environmental factors and moderately by genetic factors with stability in the magnitude over time. Mortality was added to the models as covariate to test its possible effect on the mean levels and heritability.

2. Methods

2.1. Sample

The sample consisted of participants in the OCTO-Twin study (McClearn et al., 1997; Pedersen, Steffsson, Berg, Johansson, & McClearn, 1999), which was drawn from the population-based Swedish Twin Registry (Cederlöf & Lorich, 1978). The twin pairs were included if they were born in 1913 or earlier, and both members of the twin pair were alive and willing to participate in the first measurement occasion in 1991–1994. A total of 351 twin pairs, of which 149 were monozygotic twin pairs and 202 were dizygotic twin pairs, participated in the first measurement occasion. The mean age at the baseline was 82.3. The twins were assessed in their homes by a licensed nurse at five occasions with an interoccasion interval of 2 years. Because of substantial reduction of the sample size due to mortality for the fourth and fifth assessments, only the data from the first three measurement occasions were used in the present study. The sample size and mean scores at each measurement occasion are presented in Table 1 (extraversion) and Table 2 (neuroticism) for participants and those who dropped out before the next measurement occasion because of death or other reasons.
Extraversion and neuroticism were studied using a short form of the Eysenck Personality Inventory (EPI; Floderus, 1974). The version has been widely used in the Nordic twin studies, and shown good reliability and validity (Floderus-Myrhed, Pedersen, & Rasmuson, 1980; Rose, Koskenvuo, Kaprio, Sarna, & Langinvainio, 1988; Tarkkonen, Koskenvuo, Kaprio, Langinvainio, & Floderus-Myrhed, 1981). The two subscales have nine items each, with dichotomous re-

### Table 1
Means and standard deviations (within parentheses) for extraversion in total sample, survival group and deceased group

<table>
<thead>
<tr>
<th></th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extraversion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sample</td>
<td>0.55 (0.26)</td>
<td>0.55 (0.25)</td>
<td>0.54 (0.25)</td>
</tr>
<tr>
<td>n = 482</td>
<td>n = 323</td>
<td>n = 217</td>
<td></td>
</tr>
<tr>
<td>Participated at all three measurement occasions</td>
<td>0.58 (0.24)</td>
<td>0.58 (0.26)</td>
<td>0.55 (0.25)</td>
</tr>
<tr>
<td>n = 194</td>
<td>n = 194</td>
<td>n = 194</td>
<td></td>
</tr>
<tr>
<td>Participated at the next measurement occasion</td>
<td>0.56 (0.25)</td>
<td>0.56 (0.26)</td>
<td>0.54 (0.25)</td>
</tr>
<tr>
<td>n = 303</td>
<td>n = 202</td>
<td>n = 194</td>
<td></td>
</tr>
<tr>
<td>Deceased before the next measurement occasion</td>
<td>0.53 (0.28)</td>
<td>0.50 (0.23)</td>
<td>0.54 (0.25)</td>
</tr>
<tr>
<td>n = 44</td>
<td>n = 35</td>
<td>n = 31</td>
<td></td>
</tr>
<tr>
<td>Dropped out before the next measurement occasiona</td>
<td>0.56 (0.21)</td>
<td>0.56 (0.22)</td>
<td>0.54 (0.19)</td>
</tr>
<tr>
<td>n = 135</td>
<td>n = 86</td>
<td>n = 70</td>
<td></td>
</tr>
</tbody>
</table>

*a* Includes individuals who dropped out for other reason than death.

### Table 2
Means and standard deviations (within parentheses) for neuroticism in total sample, survival group, deceased group and dropout group

<table>
<thead>
<tr>
<th></th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neuroticism</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total sample</td>
<td>0.28 (0.25)</td>
<td>0.27 (0.25)</td>
<td>0.25 (0.24)</td>
</tr>
<tr>
<td>n = 473</td>
<td>n = 318</td>
<td>n = 218</td>
<td></td>
</tr>
<tr>
<td>Participated at all three measurement occasions</td>
<td>0.23 (0.23)</td>
<td>0.24 (0.24)</td>
<td>0.24 (0.23)</td>
</tr>
<tr>
<td>n = 193</td>
<td>n = 193</td>
<td>n = 193</td>
<td></td>
</tr>
<tr>
<td>Participated at the next measurement occasion</td>
<td>0.28 (0.25)</td>
<td>0.27 (0.26)</td>
<td>0.25 (0.24)</td>
</tr>
<tr>
<td>n = 297</td>
<td>n = 202</td>
<td>n = 193</td>
<td></td>
</tr>
<tr>
<td>Deceased before the next measurement occasion</td>
<td>0.32 (0.27)</td>
<td>0.30 (0.24)</td>
<td>0.24 (0.23)</td>
</tr>
<tr>
<td>n = 41</td>
<td>n = 35</td>
<td>n = 31</td>
<td></td>
</tr>
<tr>
<td>Dropped out before the next measurement occasiona</td>
<td>0.35 (0.27)</td>
<td>0.34 (0.26)</td>
<td>0.29 (0.24)</td>
</tr>
<tr>
<td>n = 135</td>
<td>n = 81</td>
<td>n = 70</td>
<td></td>
</tr>
</tbody>
</table>

*a* Includes individuals who dropped out for other reason than death.

### 2.2. Measures

Extraversion and neuroticism were studied using a short form of the Eysenck Personality Inventory (EPI; Floderus, 1974). The version has been widely used in the Nordic twin studies, and shown good reliability and validity (Floderus-Myrhed, Pedersen, & Rasmuson, 1980; Rose, Koskenvuo, Kaprio, Sarna, & Langinvainio, 1988; Tarkkonen, Koskenvuo, Kaprio, Langinvainio, & Floderus-Myrhed, 1981). The two subscales have nine items each, with dichotomous re-
responses (0 = no, 1 = yes). In calculating the mean score in the present study, the item “Do you have any reservations about selling things or asking people for money for charity?” was excluded because it did not load on either of the factors in a confirmatory factor analysis. Means instead of sums were used to make the scores more comparable, because the number of items was different in the two scales and also differed from the number of items in the original shortened version. If an individual had more than two items missing in extraversion or neuroticism, he or she was excluded from the analysis of the personality trait in question. The Cronbach’s alpha was between 0.65–0.66 for extraversion and 0.74–0.76 for neuroticism in the three measurement occasions.

2.3. Analysis

The changes in mean scores over the three measurement occasions, including the effects of age, gender, zygosity and attrition were tested by linear mixed models in SPSS 11.5 program. Mixed models are suitable for analyzing multivariate data with correlated and non-constant variability and allow testing differences in means (fixed effects) and covariance structure (random effects). In the present study, the main effects of time (change over three measurement occasions), age, gender, zygosity and attrition (0 = participated at the next measurement occasion, 1 = died before the next measurement occasion, 2 = dropped out for other reasons before the next measurement occasion) were tested as predictors for the two personality measures. The models included two repeated (correlated) measures: the twin pair and time (three measurement occasions). For the repeated measure of time, a compound symmetry covariance structure was used. This structure assumes constant variance and constant covariance between the elements. Twinness was treated as a random effect in the models, and the covariance matrix between the members of a twin pair was assumed to have a constant structure. Model estimation was carried out using Restricted Maximum Likelihood (REML), which is adjusted for the fixed effects in the model and takes into account the degrees of freedom that are used to estimate the fixed effects.

To estimate the importance of genetic and environmental variance components for personality, the structural equation modeling software Mx (Neale, Boker, Xie, & Maes, 1999) was used. Total phenotype variance (V) was decomposed to three sources of variance: additive genetic (A), shared environmental (C), and non-shared environmental (E) effects. The assumptions for the decomposition of phenotype variance in MZ and DZ twins are the following:

\[ V_{MZ} = A + C + E, \]
\[ V_{DZ} = \frac{1}{2}A + C + E. \]

Full ACE model and its nested models were tested. To test stability and change in the heritability components over three measurement occasions, three-factor Cholesky models for extraversion and neuroticism were carried out with maximum likelihood estimation. Mx is able to deal with missing data by using raw data such that all available information in the data set can be used. The data were standardized for age and sex using a linear regression procedure prior to entry into the Mx program.

In using raw data, the absolute fit of the model cannot be tested. The difference between a full model and nested models (the difference in \(-2\ln L\)) is distributed as a \(\chi^2\) with the degrees of freedom being the difference in the number of parameters that are estimated. A significant \(\chi^2\) difference indicates that the reduction in the model significantly reduces the fit of the model to the data.
To estimate the possible effect of mortality, a dichotomized covariate indicating survival or non-survival before the next measurement occasion was added in each measurement occasion to the model (see Fig. 1). This procedure controls for the influence of mortality on the mean values. It would have been possible to add gender and age as covariates in the genetic model. Due to the small sample size, the most practical way to deal with the issue, however, was to use age and gender residualized personality scores as described above.

3. Results

3.1. Mean score stability and change in personality

The mean score stability of extraversion and neuroticism over time and the effects of age, gender, zygosity and attrition were tested using linear mixed models. Neither extraversion nor neuroticism showed significant mean score change over time (Tables 1 and 2). Age, gender and zygosity were not related to the level of extraversion, even though women showed a slight tendency to score higher in neuroticism compared to men ($F(1, 498) = 3.16, p = 0.076$). Attrition was significantly related to the level of the personality scores: individuals who died before the next measurement occasion scored lower in extraversion ($F(2, 505) = 6.26, p = 0.002$) and higher in neuroticism ($F(2, 505) = 17.38, p = 0.000$) than those who participated at the next measurement occasion. Those who dropped out for other reasons scored higher in neuroticism than those who participated at the next measurement occasion ($F(2, 505) = 16.04, p = 0.000$).

The across-time correlations of the scores showed stability over the three measurement occasions: for extraversion between 0.59 and 0.79 (mean correlation 0.71) and for neuroticism between
0.37 and 0.78 (mean correlation 0.62). The relationships between extraversion and neuroticism were modest (correlations between −0.32 and −0.38).

3.2. Genetic stability and change in personality

In extraversion, the intraclass correlations for MZ twins in the three measurement occasions varied between 0.32 and 0.55, mean correlation 0.43, and for the DZ twins between 0.05 and 0.25, mean correlation 0.14. In neuroticism, the intraclass correlations for MZ twins varied between 0.22 and 0.59, mean correlation 0.42, and for the DZ twins between 0 and 0.18, mean correlation 0.08. MZ intraclass correlations were higher than DZ correlations, implicating genetic effects on extraversion and neuroticism.

Full ACE model, and the reduced models (AE, CE and E) were tested (Tables 3 and 4). The comparison of the models showed that for both extraversion and neuroticism, shared environmental effects could be dropped out without reducing the fit of the model significantly. The additive genetic component, however, was necessary in the models.

The path coefficients in the AE model showed that additive genetic effects in Time 1 explained the genetic effects in Time 2 and Time 3 implicating a general effect over time both in extraversion and neuroticism. Non-shared environment showed considerable time-specific effects at all three measurement occasions, but also some transmission from the previous occasions. Given these observations, the AE model was elaborated further so that the additive genetic effect was measured as a general effect and equated over time, non-shared environmental effects were fixed to be time specific, and further not to cross over the measurement occasions (no influence from the previous occasions), and as a last step, mortality was added as a covariate.

For extraversion, the AE model with a general additive genetic effect with equal loadings across occasion and occasion-specific non-shared environmental effects with control for mortality was

<table>
<thead>
<tr>
<th>Model</th>
<th>$-2\ln(L)$</th>
<th>No. of parameters</th>
<th>Compare models</th>
<th>$\Delta \chi^2$ (df)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraversion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Full ACE model</td>
<td>2485.68</td>
<td>21</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2. AE model</td>
<td>2485.96</td>
<td>15</td>
<td>2 vs 1</td>
<td>0.28 (6), ns</td>
</tr>
<tr>
<td>3. CE model</td>
<td>2499.41</td>
<td>15</td>
<td>3 vs 1</td>
<td>13.73 (6)*</td>
</tr>
<tr>
<td>4. E model</td>
<td>2510.59</td>
<td>9</td>
<td>4 vs 2</td>
<td>24.63 (6)***</td>
</tr>
<tr>
<td>Further modification of model #2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1. AE model, general A factor</td>
<td>2487.57</td>
<td>12</td>
<td>3.1 vs 3</td>
<td>1.61 (3), ns</td>
</tr>
<tr>
<td>2.2. AE model, general A factor with equated loadings</td>
<td>2487.91</td>
<td>10</td>
<td>3.2 vs 3.1</td>
<td>0.34 (2), ns</td>
</tr>
<tr>
<td>2.3. AE model, general A factor with equated loadings, E factor with no effects from the previous measurement occasions</td>
<td>2562.94</td>
<td>7</td>
<td>3.3 vs 3.2</td>
<td>75.03 (3)***</td>
</tr>
<tr>
<td>2.4. AE model, general A factor with equated loadings, mortality controlled</td>
<td>2479.40</td>
<td>13</td>
<td>3.2 vs 3.4</td>
<td>8.51 (3)*</td>
</tr>
</tbody>
</table>

ns = non-significant at the 0.05 level.
* Significant at $p < 0.05$.
** Significant at $p < 0.001$. 

Table 3
The comparisons of nested three-factor Cholesky models for extraversion
the most parsimonious of the models (model 2.4 in Table 3). For neuroticism, the final AE model also included general additive genetic effects with equated loadings and time-specific non-shared environmental effects, but adding mortality to the model did not increase the fit (model 2.2 in Table 4). The final AE models are shown in Fig. 1 for extraversion and in Fig. 2 for neuroticism.

![Diagram](image_url)

Fig. 2. Additive genetic (A), and non-shared environmental (E) effects on neuroticism (NE) among old twins in three measurement occasions. g = general effect, t = time-specific effect. Raw values are shown.
4. Discussion

As expected, extraversion and neuroticism was characterized by substantial mean level stability and genetic stability over time in old people. Non-shared environmental effects were less stable over time, indicating that there were non-shared effects specific to each measurement occasion. The results confirm previous findings showing that genetic influences are more stable than environmental effects (Pedersen & Reynolds, 1998; Viken et al., 1994), but extended the previous findings to the oldest old. The study also replicated previous findings of considerable mean score stability over time in extraversion and neuroticism in old age (Kogan, 1990; Martin et al., 2002; Nilsson, 1983; Pedersen & Reynolds, 1998). Mortality affected the mean scores in extraversion and neuroticism and genetic and environmental variance in extraversion.

Mortality has been traditionally studied using survival analysis using individuals as subjects, and even integrating mortality as part of a growth curve analysis (see Mroczek & Spiro, 2005). The present study focused on twins who were over 80 year of age, and thus provided data with substantial mortality across a 4-year study period. The results replicated earlier findings of survival (Nilsson, 1983; Pedersen & Reynolds, 1998; Wilson et al., 2004), with lower extraversion scores and higher neuroticism scores among those who died before the next measurement occasion than those who survived. Moreover, adding mortality as a covariate to the genetic model increased the fit of the model for extraversion, and increased slightly the genetic component, likely reflecting a reduction in measurement error. This highlights the importance of taking into account survival when studying traits in which mortality may have impact on the means and covariance structure.

Among persons over 80 years, major developmental personality changes are not expected to occur (see Caspi et al., 2005). This study confirms that stability in personality continues into very old age, both with regards to mean scores, genetic effects and the relative importance of environmental effects over the observation period. Nevertheless, with longer time intervals genetic and mean level stability may decrease. The length of observation period before death may also be important. In the present study, personality was assessed with 2-year time intervals. The most profound effect in personality may, however, occur only during the last months or weeks before death and follow very individual patterns dependent on health status and cognitive functioning (Berg, 1996). To elucidate the effects of mortality may therefore require a shorter observation period before death than what was used in the present study.

The question of optimal time interval also applies to environmental effects. A longer time interval may decrease the impact of environmental effects between measurement occasions. Indeed, most environmental effects were occasion specific. Stability might be due to such factors as socio-economical status and living environment. Time-specific effects might include personal life events and daily hassles. Major life events may have considerable, but short-term effects on well-being, so that the previous level is regained in about a few months after the event (Suh, Diener, & Fujita, 1996). Environmental factors may affect personality, but due to genetic contribution, individuals return to the previous level after some time (see Caspi et al., 2005). An important question is the correlation and interaction between genes and environment. The present study estimated only main effects of genes and environment. In terms of personality, it is likely that certain genotypes related to certain personality traits may moderate the exposure to certain types of environmental influence.
The present study focused on personality in old–old people. When studying persons of advanced age longitudinally, the dropout due to deteriorating health and death may become high, as was also the case in the present study. Moreover, in twin studies the problems with dropout are often greater than in the studies with normal population, because both of the members of the twin pair have to be alive and able to participate in the study to be included in the analyses. A comparison of the selectivity in population samples and twin samples has shown that the greater dropout in twin samples has, however, very little effect on the results in many domains of functioning (Simmons et al., 1997). Although the statistical methods used can effectively handle missing data, the question of the representativeness of the sample remains. Assumptions about dropouts being missing at random may be violated. The survival group may represent a selected sample of old people, who are initially healthy survivors, which may affect the results, for instance by reducing the variance (see Pedersen et al., 1999). The comparison of the mean levels in the present study showed that people who died scored higher in neuroticism and lower in extraversion than people who survived. People who dropped out for other reasons than death also scored higher in neuroticism than people who participated to the next measurement occasion. Mortality was added to the models in order to control for the possible systematic error that selectivity causes in the model estimates.

Despite the greater dropout, the longitudinal genetic study of old people is important in order to shed light on genetic and environmental stability and change in personality in advanced age. The present study focused on twins over 80 years, which is a remarkably old age group in personality studies. The results generally confirmed the previous findings from extraversion and neuroticism in younger adult populations: (1) there is a high mean level stability within an individual and a group over time, (2) the effect of environment is extensive, but it does not show cumulative long-lasting effects, whereas the effect of genes is moderate, but very stable over time, and (3) mortality has important effects in mean levels and controlling for that effect also slightly increases the heritability estimates in extraversion.

Acknowledgement

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References


