**Supplemental file**

belonging to Zuidersma et al. “Temporal dynamics of depression, cognitive performance and sleep in older persons with depressive symptoms and cognitive impairments”

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**Baseline assessments**

Presence and severity of sleep disturbances were assessed with the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989). The total score can range from 0 (no sleep disturbances) to 21 (very severe sleep disturbances). In addition, participants filled out the 15-item GDS (Yesavage et al., 1983) to evaluate current presence and severity of depressive symptoms. The total score can range from 0 (no depressive symptoms) to 15 (severe depressive symptoms). In addition, medical charts were inspected to gather global cognitive performance levels at baseline according to the MMSE (Folstein et al., 1975), the MOCA (Nasreddine et al., 2005), and, if applicable, the conclusion of the multidisciplinary team of the memory clinic concerning the presence and potential cause of cognitive impairments.

**Additional information about AutoVAR**

AutoVAR (van der Krieke et al., 2015; Emerencia et al., 2016) tests all relevant assumptions and summarizes outcomes of all resulting models that meet the assumptions. It checks the stability assumption with the Phillips Perron test, and the eigenvalue test. It tests the “white noise” assumption with the Portmanteau test on the residuals, the homoscedasticity assumption with a Portmanteau test on the squares of the residuals, and normality by the Skewness test. If all these tests are non-significant a model is considered valid. If the stability assumption is not met, a linear or quadratic trend term is added to the model. If one of the last three assumptions is not met, it evaluates whether entering a lag-2 autoregressive effect, entering dummy variables for outliers, or a log-transformation of the endogenous variables results in validity of the assumptions. From all resulting valid models AutoVAR removes all redundant models (for instance, a valid model with outliers is redundant to the same valid model without outliers; so it gives priority to simpler models). From the remaining models it chooses the model with the best fit statistics (Akaike Information Criterion and Bayesian Information Criterion).

**References**

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**Supplemental Table 1: Baseline characteristics of and mean (SD) of endogenous variables over the whole study period for each participant**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Participant number** | 2 | 4 | 5 | 7 | 8 | 9 | 10 | 11 |
| **Baseline characteristics** |  |  |  |  |  |  |  |  |
| Age | 63 | 83 | 62 | 71 | 69 | 70 | 68 | 61 |
| Sex | F | M | F | M | F | M | F | M |
| Education level | Lower vocational education | General secondary education | Lower vocational education | University | Higher professional education | Lower vocational education | Higher professional education | Secondary vocational education |
| MMSE1 | 29 | NA | NA | NA | NA | NA | 30 | 22 |
| MOCA2 | NA | 25 | 24 | 25 | 24 | 25 | NA | NA |
| Diagnosis memory clinic, if applicable | MCI | NA | NA | No impairments | NA | NA | MCI | MCI |
| GDS3 | 11 | 5 | 11 | 11 | 6 | 10 | 8 | 12 |
| PSQI4 | 18 | 17 | 9 | 3 | 5 | 16 | 12 | 7 |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
| **Time series** |  |  |  |  |  |  |  |  |
| T5 (days) | 37 | 94 | 64 | 64 | 63 | 64 | 78 | 71 |
| **Sleep**6 **(TST)** |  |  |  |  |  |  |  |  |
| Number of missing values7 | 1 | 32 | 1 | 1 | 12 | 1 | 4 | 1 |
| Mean (SD) | 7.5 (1.0) | 8.9 (1.4) | 7.5 (0.6) | 7.1 (0.6) | 7.4 (1.1) | 7.6 (1.0) | 6.1 (1.1) | 8.1 (1.3) |
| **Depressive symptoms8** |  |  |  |  |  |  |  |  |
| Number of missing values7 | 4 | 2 | 3 | 3 | 7 | 4 | 12 | 19 |
| Mean (SD) | 4.6 (0.6) | 3.0 (0.3) | 3.6 (0.3) | 5.0 (0.5) | 1.7 (0.8) | 2.1 (0.3) | 1.8 (0.7) | 3.2 (0.7) |
| **Working memory9** |  |  |  |  |  |  |  |  |
| Number of missing values7 | 4 | 4 | 3 | 3 | 13 | 15 | 12 | 24 |
| Mean (SD) | 874 (101) | 744 (98) | 638 (96) | 648 (73) | 618 (52) | 638 (31) | 912 (84) | 721 (181) |

1 Mini-mental state examination score indicating cognitive performance: possible range: 0 (worst cognitive performance) – 30 (best cognitive performance)

2 Montreal cognitive assessment score indicating cognitive performance: possible range: 0 (worst cognitive performance) – 30 (best cognitive performance)

3 Geriatric Depression Scale score indicating severity of depressive symptoms during the past week: possible range 0 (no depressive symptoms) – 15 (very severe depressive symptoms)

4 Pittsburgh Sleep Quality Index total score indicating sleep quality during the past month: possible range 0 (no sleep problems) – 21 (very severe sleep problems)

5 T is the length of the time series in days. It deviated from the protocolled 64 for some participants due to practical reasons (e.g. holidays (n=2), could not persevere the study (n=1), the electronic diary automatically stopped 1 day too early (n=2), intrinsic motivation to go on longer to compensate for missing values (n=2))

6 Sleep comprised the total night-time sleep time of the last night in hours

7 Indicates the number of missing values in the time series of that participant (so for participant 1, 7 out of the 54 sleep assessments were missing).

8 Depressive symptoms comprised average PHQ scores with possible range of 1 (absent) to 7 (most severe)

9 Working memory performance comprised the reaction time for correct answers on the One Back Task in milliseconds

T=length of time series, GDS=Geriatric Depression rating Scale score, IQR=interquartile range, MMSE=Mini Mental State Examination score, NA=not assessed, PHQ=Patient Health Questionnaire; PSQI=Pittsburgh Sleep Quality Index; SD=standard deviation, TST=total sleep time (in hours)

**Supplemental Table 2: Cumulative effect size over 10 days based on COIRF for significant Granger causality or contemporaneous associations between endogenous variables**

|  |  |  |  |
| --- | --- | --- | --- |
| **Participant** | **Association** | **β (SE/99%CI) Order 1** | **β (SE/99%CI) Order 2** |
| 4 | Working memory 🡪 depression | 0.51 (-0.02 – 1.33) | 0.31 (-0.43 – 1.18) |
| 7 | Working memory 🡪 depression | -0.59 (-1.14 – 0.05) | -0.58 (-1.27 – 0.27) |
| 8 | Sleep 🡪 working memory | -0.13 (-0.30 – 0.04) | NA |
| 10 | Sleep 🡪 depression | 0.24 (-0.12 – 0.52) | NA |
| 11 | Depression 🡪 working memory | **-0.35 (-0.63 - -0.01)** | **-0.26 (-0.50 - -0.02)** |

COIRF=cumulative orthogonalized impulse response function analysis, NA=not applicable, because the contemporaneous association of sleep with depression/cognition was always in the order from sleep to depression/cognition; β: standardized effect size over a 10-day horizon; the COIRF was performed only for significant Granger causality or contemporaneous associations between endogenous variables. Confidence intervals were calculated by performing 100 bootstraps. Order 1: assumed contemporaneous relationship is the same as the investigated lagged relationship (so for participant 4 the assumed contemporaneous relationship is that working memory precedes depression), Order 2: assumed contemporaneous relationship is the reverse of the investigated relationship (so for participant 4 the assumed contemporaneous relationship is that depression precedes working memory). **Bold** are those associations that do not include 0 in the 99% CI.

Depressiont-1

Cognitiont-1

Depressiont

Cognitiont

Sleept

Sleept-1









**Supplemental Figure 1: Cumulative Orthogonalized Impulse Response Function (COIRF) for those associations with significant Granger causality**. Shows cumulative response pattern of the response variables in response to 1 SD in the impulse variable over a period of 10 days. Because all endogenous variables were standardized, the effect size represents a standardized effect size. Dotted lines represent 99% confidence intervals.