Executive function measures of cognitive flexibility are associated with days of sick leave

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ABSTRACT

Psychological constructs related to health outcomes and well-being, such as metacognitive beliefs, have been linked to executive functions capacity in general, and cognitive flexibility in specific. However, these constructs are measured through self-report, only approximating information processing capacities. Objectively measured executive function capacity may be a more potent predictor of health outcomes. Based on this idea, we set out to test whether executive functions capacity, with a focus on cognitive flexibility, was associated with sick leave in a medium sized company. We included 111 subjects of widely different occupations and assessed their executive functions using Delis-Kaplan Executive Function System test battery (D-KEFS). Our prime tests were *Design Fluency* (*DF*) and *Verbal Fluency* (*VF*), as they have a focus on cognitive flexibility, and we included them into an index denoted *DFVF*. Detailed information on sick leave for the last five years was gathered from the company. Our results suggested that there was a significant negative correlation between *DFVF* and sick leave (Spearman's rho $r_s(111)=-0.25$, $p=0.007$) in the full group as well as in the group that had at least one day of sick leave (Spearman's rho $r_s(74)=-0.305$, $p=0.008$). The results withstood adjustment for sex, age, occupation, processing speed, and core EF including simple attention, short-term memory, working memory and inhibition in an ANOVA-analysis. The results also remained for separate analyses using *DF* or *VF*. The study suggests that objectively measured capacity of cognitive flexibility is associated with key health outcomes such as sick leave, mirroring previous research on metacognitive beliefs.

INTRODUCTION

A decision to go on sick leave or when to return to work involves personal beliefs and psychosocial factors beyond any specific diagnosis. As an example of this, metacognitive beliefs that guide our information processing have been shown to regulate behavior (1), affect health outcomes (2), and change stress reactivity (3). In addition, rigid metacognitive beliefs about the necessity of controlling mental content have been associated with extended periods of sick leave (4). The underlying cognitive composition in terms of information processing and control of metacognition has sparked interest into the relation between Executive Functions (EF) and metacognitive processes (5). Here, objective executive functioning can been seen as representing an operationalization of how to measure behavioral and information processing effects of metacognitive beliefs (6). As an example of this, metacognitive beliefs extends thinking through excessive worrying and rumination, keeping our attention geared toward perceived internal or external threats. This can be both tiring and rigid, over time challenging our information processing hierarchy and flexibility, reducing executive functioning (7). Also, low basal cognitive flexibility capacity may influence metacognition in a deleterious way increasing rumination on negative thoughts instead of finding other alternatives (7).

EF is an umbrella term describing cognitive processes that regulate thoughts and actions especially in non-routine situations (8-10). The capacity of top-down regulation is distributed normally among a general population, and neuropsychiatric disorders like ADHD and autism are associated with low EF capacity in this distribution (11, 12). *Cognitive flexibility* (sometimes also denoted *cognitive shifting*, *mental flexibility* or *set shifting*) is an executive function that refers to the ability to switch mentally between tasks and rules, as well as shifting back and forth between multiple tasks, operations, mental sets or strategies (8, 9, 13). It is associated with the ability to adjust to changed demands and is the opposite of rigidity (8). Notably, rigid metacognitive beliefs about the necessity of controlling thoughts have been associated with a decreased ability to shift between mental sets (5) suggesting a lack of involvement of cognitive flexibility. Thus, apart from EF in general, cognitive flexibility may, in specific, be closely associated with metacognitive capabilities that open up for and predict beneficial health outcomes. In addition, EF are often viewed as key components in other psychological constructs related to health outcome and well-being such as *psychological flexibility* (14-17), *resilience* (18-20), and *locus of control* (21).

Related to health and well-being, it has been suggested that EF in general, and cognitive flexibility specifically, are important for successful behavior in diverse situations, speaking for its generic importance for individuals across demands. For example, we have previously shown that elite soccer players have better EF capacity, especially cognitive flexibility, than semi-elite players and population norm (22-24). Along a similar line it has been suggested that cognitive flexibility is related to successful behavior associated with elite police forces tasks (25), and transformational leadership in management (26).

In the present study, we aimed to move away from psychological constructs and instead test the hypothesis of whether an objective measure of EF capacity, with a focus on cognitive flexibility, is associated with sick leave. In order to test our assumption, we assessed EF in different occupational positions in a mid-size Swedish company that included strategic managers, operational managers, sellers and forklift operators. Thereby, we could also adjust for differences in socioeconomic status. We hypothesized that higher capacity of EF related to cognitive flexibility, would correlate negatively with reported sick leave over five years (see further supporting information).

METHODS

Ethics

The study was approved by the local ethical committee in Stockholm (2018/2574-31/1 2019-00223) and was performed in compliance with the Declaration of Helsinki. All subjects were given verbal and written information on the study and gave their verbal and written informed consent to participate.

Procedure

The subjects went through the assessment at their working place. The assessments were made from March to June 2019. The subjects were tested in a standardized process with six test-leaders, trained and overseen by a licensed psychologist for this particularly assessment. There were no significant differences of the test results between the test-leaders.

Participants

The study was performed in collaboration with a medium sized company in the wood products industry (Derome). A total of 111 co-workers between 22 and 67 years (mean age = 44.2, SD = 10.85; 94 males) participated (**Figure S1**). Derome’s HR department offered employees to participate in the study. Strategic managers, operating managers, sellers and forklift operators were included, mirroring different categories of employees in the company. The participants represented a cross-section of sex, age and geographic location. Apart from these criteria, the employees were asked at random whether they would like to participate in the present study. Some exceptions were made concerning the location. If two employees were considered equivalent, the employee was chosen that was stationed closest to the places where the assessment was performed. The final sample that was tested consisted of 27 forklift operators (mean age=43.3, SD=14.4; 24 males), 25 sellers (mean age=42.4, SD=11.4; 18 males), 27 strategic managers (mean age=46.6, SD=8.4; 22 males) and 32 operative managers (mean age=44.5, SD=8.7; 30 males). There were no significant differences between the employment categories in terms of age or sex (age=$p>0.54$; sex= $p>0.13$). None of the participants were on sick leave at the time of testing.

Materials

D-KEFS

We used the neuropsychological test instrument *The Delis-Kaplan Executive Function System test battery (D-KEFS*) for our main cognitive assessments (27). D-KEFS is a test battery measuring different aspects of EF. All tests in the battery are performance tests. Primary measurement is often time in seconds. Secondary measurement is often accuracy. D-KEFS is used in clinical assessments and there are well-described norms for the general population. A test-retest reliability analysis for the D-KEFS tests has been performed on the D-KEFS norm group (1750 individuals stratified on age, sex, ethnicity and education) in the US and showed a moderate to strong reliability (27). D-KEFS tests show a normal distribution in healthy subjects (27, 28) and the results relate to brain morphology (29, 30) within networks involved in EF (31).

Subtests of D-KEFS

Design Fluency (***DF***), is a standardized test which measures on-line multi-processing such as planning, working memory, visual scanning, creativity, response inhibition, and cognitive flexibility (8, 27, 32, 33) and thus simulates the executive chain of decision making that may be relevant for fast and accurate behavior. Especially, cognitive flexibility and the closely associated creativity components are emphasized in these tasks. It has also been argued that *DF* is a test of higher executive functions (HEF) since it incorporates several core executive functions (CEF) that are used in order to complete the task (24, 27, 34). *DF* is a non-verbal psychomotor test in which the participant uses a pen to combine dots in a square with four lines. In *Condition 1* (*Design Fluency 1*; *DF1*) the task is to find as many different combinations as possible of binding together filled dots under time pressure (60 seconds) and the participant is not allowed to use a solution twice. In *Condition 2* (*Design Fluency 2*; *DF2*) unfilled dots have been added to the square, and the task is to combine them with lines as in Condition 1. The filled dots are still present but the participant is not allowed to use them in the task. In this condition the task raises the general level of difficulty due to more need from response inhibition (27). In *Condition 3* (*Design Fluency 3*; *DF3*) both filled and unfilled dots are still present, and the task is to connect lines as above but also to constantly switch between a filled and an unfilled dot. Thereby, the task difficulty increases through the raised demand on the subject's ability in cognitive flexibility (27). All scores are expressed as normalized values adjusted for age and sex.

***Verbal fluency* (*VF*)** is a standardized task that, like *DF*, measures on-line multi-processing such as planning, working memory, creativity, response inhibition, and cognitive flexibility, but with a semantic output (8, 27). In *Condition 1* (*Verbal fluency 1; VF1*)*, Letter Fluency*, the task is to say as many words as possible on a given letter during 60 seconds without making any repeats and observing several rules and restrictions. In *Condition 2* (*Verbal fluency 2; VF2*)*, Category Fluency*, the task is to say as many words as possible from a given category during 60 seconds without repeating words. In *Condition 3* (*Verbal fluency 3; VF3*)*, Category Switching*, the task is to say as many words as possible in 60 seconds without repeats from two different categories and alternating between the categories after every reported word. All scores are expressed as normalized values adjusted for age and sex.

Primary outcome

In accordance with our hypotheses (see Supporting Information) our primary outcome was a combined measurement (mean of scaled scores) of *DF1* (Filled dots), *DF2* (unfilled dots), and *DF3* (switching) together with *VF1* (Letter), *VF2* (Categories), and *VF3* (Switching) to capture the creative abilities of generating solutions, rely on a creative ability paired with cognitive flexibility on both a visuo-spatial and verbal HEF level. By using a composite score (average normalized score of *DF1-3* and *VF1-3*), we also reduced the noise of temporary test failures of the subjects. This primary index is referred to as *DFVF* (Design Fluency/Verbal fluency)

Secondary outcomes

Color word interference **(*CWI*)** is a *Stroop-test* involving verbal inhibition (8, 27) and **CogStateSports (CS)** is a non-verbal psychomotor test battery that measures basic attention, cognitive process speed, decision-making, speed and accuracy of short-term memory and encoding of working memory (35, 36). These tests were used for exploratory reasons and for adjusting for low-level executive functions and CEF. They are further described in the Supporting Information.

Data on occupation, employment and sick leave

The company sampled sick-leave data for all their employees. With permission from the test subjects, we collected information from the company that included occupation, months of employment and days of sick leave they have had five years back counted from the first of September 2019 (Mean=50.6; Median=60; SD=15.8; Min=3; Max=60). The days of sick leave were then divided by how many months they have been employed.

Statistical analysis

We first set out to test whether our primary measurement of cognitive flexibility and HEF (*DFVF*) correlated with days of sick leave in the total studied population (main hypothesis; supporting information). Due to a highly skewed sick leave data a non-parametric correlation test (Spearman's Rho, two-tailed) was performed in this analysis.

In order to exclude that the group with no sick-leave was driving a putative association between cognitive flexibility and HEF on the one hand, and sick leave on the other, we further analyzed only subjects that had at least one day of sick leave (secondary hypothesis; Supporting Information). As we also wanted to adjust for various possible confounds (see below) a log10 adjustment of the data was performed in order to achieve a normal distribution in this group. In order to be transparent, we first analyzed this data using both a simple non-parametric-analysis as above (Spearman's Rho) and a simple parametric analysis on the log transformed data (Pearson correlation). An ANCOVA was then used to compute the correlation between the amount of sick leave (log10 transformed) and *DFVF*, adjusting for *age, sex*, and *working group*. In order to more specifically test for the relation between cognitive flexibility and sick leave we also adjusted for processing speed, low level cognitive processes and CEF (including simple attention, short-term memory, working memory and inhibition).

We further made a contrast measurement (in the ANCOVA) and a post hoc analysis (using Tukey's HSD) to explore if there was a difference in *DFVF* and sick leave between the different categories of employees. Finally, we explored whether *DF* (average of *DF1-3*) and *VF* (average of *VF1-3*) as well as all sub-measures(*DF1*, *DF2*, *DF3*, *VF1*, *VF2* and *VF3*) independently contributed to the results using the same ANCOVA-analyses as above.

Data were analyzed using IBM SPSS Statistics 25. Shapiro-Wilk test was used to test distributions for normality. Levene's test was used to test the homogeneity of variances between the groups.

RESULTS

Sick leave

For the whole group (n=111) the mean of sick leave days the last five years was 0.38 days per month. Median sick leave was 0.083 days per month (Min=0; Max=7.5, SD= 0.95). While 74 of the included subjects had at least one day of sick leave during the last five years (Mean=0.56 days per month; Median=0.19; Min=0.02; Max=7.50, SD=1.12), 37 of the participants had no days of sick leave. Due to the skewed distribution a log10 calculation was applied to the sick leave data for the ANCOVA that included subjects that had at least one day of sick leave during the last five years (**Figure S2**).

Relation between DFVF and sick leave in the full group

We first performed an analysis that included all subjects studied where we had data on both sick leave and *DFVF* (n=111). The non-parametric correlation analysis showed a significant negative correlation between *DFVF* and sick leave (Spearman's rho $r_s(111) = -0.25$, $p = 0.007$). Two subjects displayed sick leave more than 3 SD above the mean. Repeating the analyses with these subjects removed rendered a similar result (Spearman's rho $r_s(109) = -0.23$, $p = 0.018$).

Relation between *DFVF* and sick leave in subjects with sick leave

To investigate the quantitative relation between degree of sick leave and cognitive flexibility, we performed an analysis of the group that had at least one day of sick leave the last five years. We first tested whether the effects that we observed for the whole group remained for the group of subjects that had at least one day of sick leave the last five years (n=74) using non-parametric correlational tests as above. The analysis showed a significant negative correlation between *DFVF* and degree of sick leave (Spearman's rho $r_s(74) = -0.305$, $p = 0.008$). After a log10 adjustment of the sick leave data (denoted as ***Sick leave log 10***) due to the skewed distribution, a normal distribution of the data was obtained (**Figure S2**). A significant negative correlation between sick leave (*Sick leave log 10*) and *DFVF* remained in this analysis (Pearson's r; $r = -0.34$, $p = 0.003$,) as illustrated in **Figure 1**.

Figure 1.

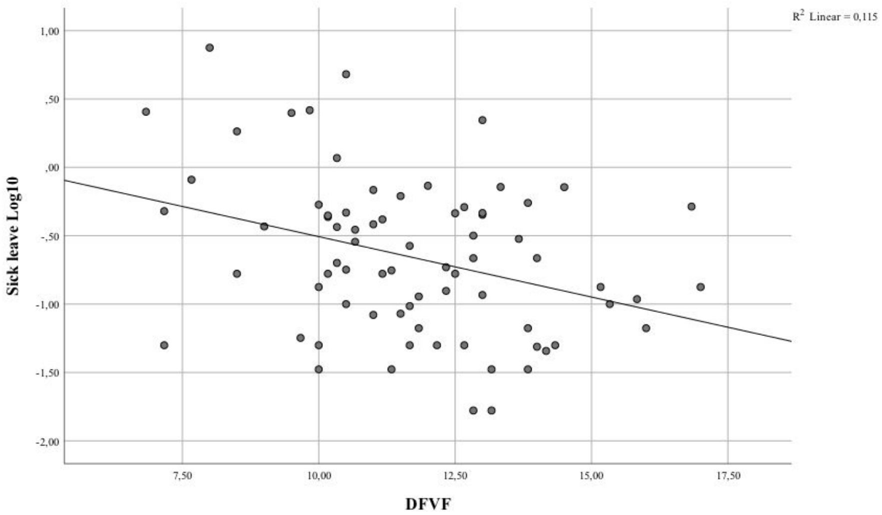

Figure 1. The correlation between our composite measure of design fluency and verbal fluency capacity (*DFVF*) and average number of sick leave days per month during the last five years (log10 transformed) for the subgroup who displayed at least one sick leave day during the observed period.

Relation between *DFVF* and sick leave adjusting for other parameters

An ANCOVA test was then performed to study the relation between sick leave (*Sick leave log 10*) and *DFVF* when adjusting for *sex, age, working group* as well as *processing speed*, *simple attention, short-term memory*, *working memory* and *inhibition* (to control for low level cognition and CEF). In the analysis, the main effect of *DFVF* on sick leave was significant ($F(1, 62) = 10.84$, $p = 0.002$, $\eta_p^2 = 0.15$, $r = 0.39$, $d = 0.84$), suggesting that better results on *DFVF* correlated with lower sick leave. We also found a significant effect of group ($F(3, 62) = 5.27$ $p = 0.003$, $\eta_p^2 = 0.20$, $r = 0.45$, $d = 1.00$) and inhibition ($F(1, 62) = 7{,}911$, $p = 0.007$, $\eta_p^2 = 0.11$, $r = 0.33$, $d = 0.7$) in this model, indicating that better *inhibition* capacity correlated with lower sick leave. The other independent variables (sex, age, processing speed, simple attention, short-term memory, and working memory) did not show a significant effect on the score of *Sick-leaveLog10* as illustrated in **Table S1.** The model adjusted R squared was 0.26. The model assumption was met according to Levene's test of equality of residual variances ($p = 0.22$) and Shapiro-Wilk test for normality of the residuals ($p = 0.24$).

An exploratory contrast measurement, made in the ANCOVA, revealed that there was a significant lower amount of sick leave among the strategic managers ($p = 0.002$, 95% CI [-0.96, -0.22]) as well as the operating managers ($p = 0.004$, 95% CI [-0.81, -0.16]) compared with the forklift operators. No significant difference between sellers and fork lift operators ($p = 0.67$, 95% CI [-0.47, 0.30]) was found.

Post-hoc analyses of the result of *DFVF* in the different working groups

A post-hoc analysis on the full group (n=111), using Tukey's HSD indicated that the scores of *DFVF* were significantly higher for the strategic manager ($p = 0.002$), operating managers ($p = 0.017$), and seller ($p = 0.022$) compared with forklift operators. Restricting the analyses to the group with at least one day of sick leave (n=74), indicated that the scores of *DFVF* were significantly higher for the operating managers ($p = 0.031$) compared with forklift operators. Sellers ($p = 0.062$), and strategic managers ($p = 0.14$) did not display significantly higher results than forklift operators.

Relations between sick leave and *DF* and *VF*, respectively

To explore if the verbal and the visuo-spatial part of the fluency measurement are independently associated with sick leave, an ANCOVA was performed in the same way as for *DFVF* but separately for *DF* (Design fluency) and *VF* (Verbal fluency) using the log-transformed results related to sick leave (sick leave log 10) in the subjects that had at least one day of sick leave.

This analysis showed that the main effect of *DF* was significantly related to sick leave ($F(1, 62) = 5.97$, $p = 0.017$, $\eta_p^2 = 0.088$, $r = 0.3$, $d = 0.62$). A significant effect for group ($F(3, 62) = 4.87$ $p = 0.004$, $\eta_p^2 = 0.19$) and inhibition was also observed ($F(1, 62) = 5.06$, $p = 0{,}028$, $\eta_p^2 = 0.75$). The other independent variables (sex, age, processing speed, simple attention, working memory, and short-term memory) did not show significant effect on the score of *Sick-leaveLog10,* as illustrated in **Table S2**. The model adjusted R square was 0.21. The model assumption was met according to Levene's test of equality of residual variances ($p = 0.18$) and Shapiro-Wilk test for normality of the residuals ($p = 0.117$).

Moreover, the main effect of *VF* was also significantly related to sick leave ($F(1, 62) = 7.08$, $p = 0.01$, $\eta_p^2 = 0.10$, $r = 0.32$, $d = 0.67$). There was significant effect of group ($F(3, 62) = 5.6$, $p = 0.002$ $\eta_p^2 = 0.21$) and inhibition ($F(1, 62) = 6.55$, $p = 0.013$ $\eta_p^2 = 0.096$). The other independent variables (sex, age, processing speed, simple attention, working memory, and short-term memory) did not show a significant effect on the score of *Sick-leaveLog10* as illustrated in **Table S3**. The model adjusted R square was 0.22. The model assumptions were met according to Levene's test of equality of residual variances ($p = 0.16$) and Shapiro-Wilk test for normality of the residuals ($p = 0.41$).

Finally, for transparency we present how *DF1-3* and *VF1-3* independently related to sick leave in subjects who had at least one day of sick leave. In general, all subtests seemed to have a similar relation to sick leave (**Table S4**).

DISCUSSION

The results of this study supported our main hypothesis, by showing that a composite score incorporating both design fluency and verbal fluency (*DFVF*) correlated inversely with degree of sick leave in a mixed population of employees at a mid-size company. This effect was shown for the full group as well as for the subgroup that had at least one day of sick leave during the last five years. In the subgroup, the effect remained when adjusting for sex, age and occupation as well as for several low-level cognitive measures like general response speed, simple attention, short-term memory, working memory and inhibition. By adjusting for these factors, it is unlikely that basic cognitive functions and other CEF contributed to the results. This suggests that a combination of cognitive flexibility and fluency may be the main factor relating to the degree of sick leave.

The preset result is of interest since sick leave is an important indicator of health and work ability. While influential psychological models such as *metacognitive theory* (2-5, 7), *psychological flexibility* (14-17), *resilience* (18-20) and *locus of control* (21) imply that EF and cognitive flexibility may be an important aspect of a positive health outcome, this has not been specifically tested in a normally working population. In line with such a hypothesis, we show that capacity of cognitive flexibility measured with neuropsychological tests, is related to a central health outcome such as sick leave. Below we discuss the relation between these psychological concepts, EF and health outcomes.

Of particular interest here is that design and verbal fluency can be viewed not only as tests of flexibility but also tests of creativity within a set of rules. In order to be successful on the test, relevant rules must be selected, understood and actions planned. Moreover, the chosen strategies must be flexibly adjusted and the utility of strategies constantly evaluated. All of these functions are metacognitive in nature, making it tempting to speculate that the current association between fluency and work participation could be mediated by flexible metacognitive strategies and beliefs. Past research has shown how rigid and negative metacognitive beliefs affect duration of sick leave (4). Such beliefs also have a negative effect on mental capacity (37) and are associated with subjective cognitive deficiencies (7). Moreover, negative metacognitive beliefs have been linked to objective neuropsychological impairments (5), cognitive flexibility in particular. Thus, the association between cognitive flexibility and metacognitive capacity may go both ways.

The results of our study are also in line with previous studies indicating a negative relation between psychological flexibility and sick leave in chronic pain patients (15, 38). However, in those studies psychological flexibility was estimated from self-ratings, while the capacity of cognitive flexibility from a more objective performance measurement was not measured.

A systematic literature review (39) showed that the three most common reasons for sick leave were back- and neck pain, cardiovascular disorders and mental disorders. Our study did not differentiate between causes for sick leave. However, we suggest that both mental and somatic health may be influenced by HEF and cognitive flexibility capacity, and thereby work ability. A well-developed cognitive flexibility may work as a resilience factor and directly decrease the accumulated stress level, since the individual tends to solve the problems at stake, that, in turn, may impact on health relevant factors such as immune function, sleep and pain processing (40-43).

Similarly, cognitive control of demanding situations may influence the perceived control as well and thus buffer stress level and contribute to adaptation (44). In speculation, such control and the ability to properly adapt behaviors to demands may contribute to perceived work ability and thereby a lower inclination for sick leave. In support of this proposition, several studies indicate that low job control, among other factors, is associated with higher risk for sickness absence (45-47) and predicts early return-to-work in sick listed employees (46).

All the factors discussed above have a putative effect on both subjective and objective correlates of health, and thereby sick leave mediated by EF and cognitive flexibility. However, there are alternative explanations behind the current results. Both *VF* and *DF* also include other cognitive aspects than cognitive flexibility. Although *DFVF* was related to sick leave also when adjusting for other cognitive variables (e.g. general attention, processing speed, short term memory, working memory and inhibition), it cannot be excluded that other cognitive variables do not influence the results. Although closely associated to cognitive flexibility, cognitive fluency and creativity, *DF* and *VF* may involve additional EF processes not accounted for (8, 27, 28). More specific motor, perceptual and language components may impact the test results (32, 48). It may for example be of importance how well developed language a subject has for the *VF* result or how well-developed, low-level perceptual abilities a subject has for the *DF* results. However, we show that both *VF* and *DF* contribute to this relation. Moreover, the complexity of the tests may also have influenced the results, as both *VF* and *DF* may be regarded as HEF tests involving many simultaneous EF and non-EF components increasing the general cognitive load on the information processing system. Finally, high EF are associated with better emotional regulation (12, 43), including regulation of pain as well as anxiety and depression, and may explain our results independent of any relation to the discussed psychological models. In order to link our findings to the psychological models presented previously, the relation between tested cognitive flexibility capacity and measurements of behavioral flexibility in life needs to be investigated.

Although our results are novel for the normally working population they are in line with several studies on patients. For example it has been shown that EF may predict absence from work following in-patient occupational rehabilitation (49). Another study compared remitted bipolar patients that were able to continue to be active (studying or working) with those who were inactive (e.g. unemployed, received early retirement benefit or being on long term sick leave) (50). The group that still was active had significantly better EF capacity including cognitive flexibility, but did not differ in terms of IQ, as compared to the inactive group. These results complement those of our study, which showed a similar relation between EF and sick leave in a normal working population. Apart from the difference in studying patients vs. normal population, our study showed that the results remained after adjusting for several core executive functions, while the bipolar patient study discussed above (50) suggested that the effect was not related to IQ-level. An advantage with the present study as compared to registry-based studies is that short-term sick leaves (obtained from the employer) was included and not only sick-leaves of 14 days or longer as registered by the Swedish Social Insurance Agency.

The results from this study also showed that the amount of sick leave was significantly lower for strategic managers and operating managers compared to sellers and forklift operators. Furthermore, in the 74 subjects who had been on sick leave, the operating managers and sellers had significant higher HEF score than the fork lift operators, and in the full group (n=111) strategic managers, operating managers and seller had better HEF than forklift operators. However, it is unclear if the difference in sick leave between the groups is a consequence of different HEF or different opportunities for a temporary change of their working situation. Thus, we cannot exclude that lower sick leave among managers could be a result of a better opportunities for a temporary change of their working situation and a possibility to work from home when being ill. Another difference between the occupations, that may drive the different HEF results is that managers in general make decisions in a constantly changing external and global environment, while sellers and forklift operators have more of a clear and set goal with less possibility of adjusting their behaviour. Better HEF capacity among managers could therefor mirror a need for dynamic adjustment associated with the assignment. A secondary consequence of well-developed HEF could be that managers are less vulnerable to stress and therefore have less sick leave (51). Although these differences between the occupations were observed it is important to stress that our main result showing a negative correlation between sick leave and the *DFVF* remained even when adjusting for occupation. Thus, the main result seems not to be dependent on socioeconomic status.

There are a number of limitations in this study. Since IQ was not measured this is a clear limitation. Moreover, reversed causality cannot be excluded with the present design. Thus, reduced EF may be a consequence of previous health problems, rather than the opposite. It is, for example, possible that previous depression is related to a deteriorating EF capacity. Likewise, although no subjects were on sick leave at time for assessment, it is possible that subjects with a high degree of sick leave experienced sub-clinical levels depression, anxiety, sleep problems or other health problems that might negatively impact of the higher order of executive functions capacity when tested. Thus, the study cannot show that EF-capacity predicts number of sick-days. Another limitation is that we did not measure psychological flexibility and can only speculate about how it may relate to cognitive flexibility capacity.

On a more general level this study suggest that well-developed EF could have a positive impact in healthy and fully functioning subjects. It is aligned with previous studies showing a relation between EF and high performance in ball sports (22-24), elite police officers (25) and leadership positions (26). The results also suggest a cognitive mechanism, i.e. cognitive flexibility, that may underlie a general flexible behavior emphasized in several psychological constructs and often rated subjectively. Further studies should better describe this possible link between flexible behavior in life and an objectively measured cognitive core capacity (12).

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Supporting Information

Executive function measures of cognitive flexibility are associated with days of sick leave

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Hypotheses

Main hypothesis: *DFVF*, an index representing HEF that includes a high degree of cognitive flexibility, is associated with sick-leave in the studied population.

Secondary hypotheses: *DFVF* is associated with sick-leave in the subpopulation consisting only of individuals with at least on day of sick-leave. The relation remains when adjusting for sex, age, working group, processing speed, and CEF (including simple attention, short-term memory, working memory and inhibition).

Exploratory analysis: Is *DFVF* different in relation to the different occupations? Are *VF* and *DF* separately associated with sick-leave?

Additional tests that were used

Additional cognitive tests that were not part of the main hypothesis but used to adjust for cognitive low level processes and CEF in our models.

Color word interference **(*CWI*)** is a *Stroop-test* involving verbal inhibition (8, 27) from D-

KEFS test battery (27). In test-condition 1 (*CWI-1*) the participant is instructed to say the printed color of the squares (green, blue and red) line by line from the top to the bottom of a paper. In test-condition 2 (*CWI-2*) the participant is instructed to read the color words (green, blue and red) in black line by line from the top to the bottom of a paper. In test-condition 3 (*CWI-3*) all color words (green, blue and red) are either printed in the congruent or incongruent color and the subject is instructed to report the printed color. The test captures response inhibition and represents the classical form of the Stroop task.

CogStateSport

CogStateSports (CS) is a non-verbal psychomotor test battery that measures basic attention, cognitive process speed, decision-making, speed and accuracy of short-term memory and encoding of working memory (35, 36). The subjects are shown different playing cards on a computer screen and have to react as fast and correct as possible using different key responses. In the first test ("***Processing speed***"), measuring simple response time, the subject has to respond to any card that is displayed. In the second test ("***Attention***"), measuring simple attention, the subject has to respond whether the card is red or black. In a third test ("***Learning***") the subject has to respond if he or she has seen the displayed card any time earlier in the test sequences - a measure of more demanding working memory and learning. In the fourth test ("***Working memory***"), measuring the short-term memory, the subject has to decide if the previous card is the same as the card before (i.e. one-back memory-test).

Figure S1.

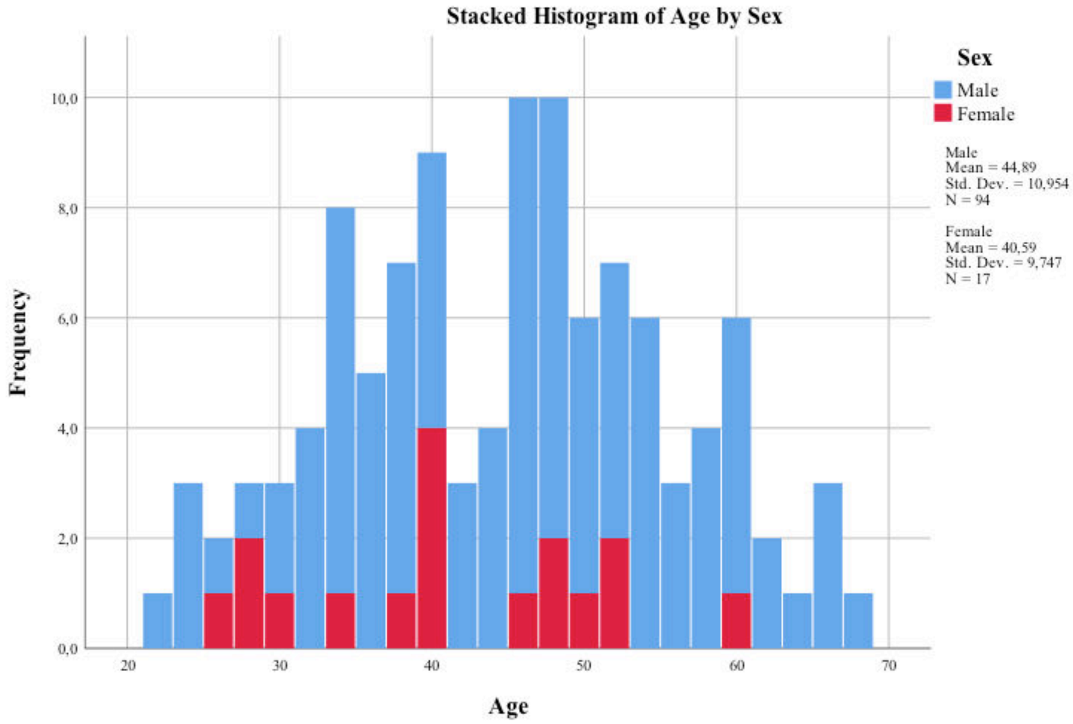

Figure S1. Age frequency of the test-group.

Figure S2.

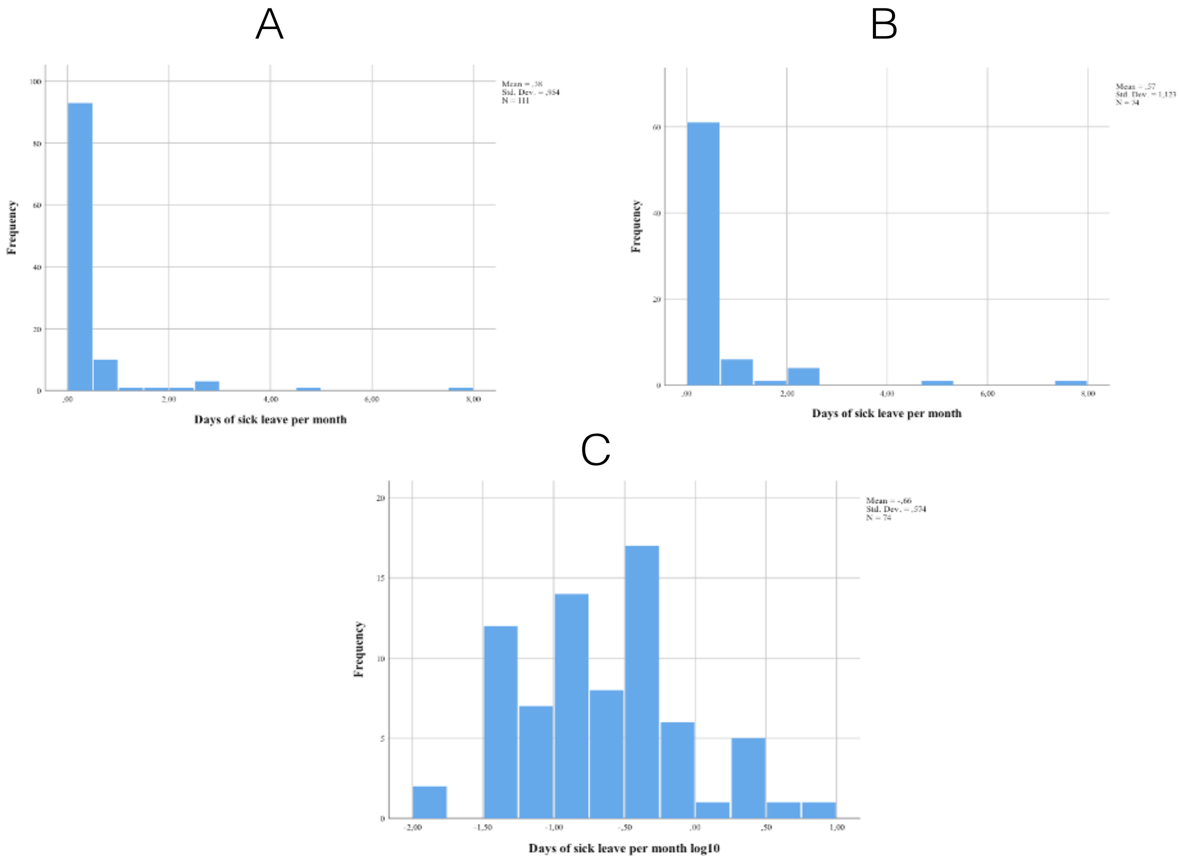

Figure S2. A) Histogram of the distribution of the sick leave the last 5 years (day per month) in A) the full group of subject (n=111) and B) the group that had at least one day of sick leave the last five years (n=74). C) Log 10 of the sick leave the last 5 years (day per month) in the group that had at least one day of sick leave the last five years. This data was normally distributed (Shaprio-Wilk p=0.20).

Table S1.

Source	df	F	Sig.	Partial Eta Squared
Corrected Model	11	3.33	0.001	0.37
Working Goup	3	5.27	0.003	0.20
Sex	1	0.58	0.45	0.01
Age	1	0.12	0.73	0.00
Processing speed	1	0.18	0.68	0.00
Attention	1	1.04	0.31	0.02
Working memory	1	0.01	0.93	0.00
Short-term memory	1	0.12	0.74	0.00
Inhibition	1	7.91	0.007	0.11
DFVF	1	10.84	0.002	0.15

Table S1. ANCOVA-analysis showing the effect of *DFVF* on the score of *Sick-leaveLog10* while adjusting for other variables. Data concerning significance level and effect size of all independent parameters in the main ANCOVA.

Table S2

Source	df	F	Sig.	Partial Eta Squared
Corrected Model	11	2.73	0.006	0.33
Working goup	3	4.87	0.004	0.19
Sex	1	0.01	0.92	0.00
Age	1	0.00	0.98	0.00
Processing speed	1	0.24	0.63	0.00
Attention	1	1.75	0.19	0.03
Working memory	1	0.34	0.56	0.01
Short-term memory	1	0.00	0.94	0.00
Inhibition	1	5.06	0.028	0.075
Design Fluency	1	5.98	0.017	0.09

Table S2. ANCOVA-analysis showing the effect of *DF* on the score of *Sick-leaveLog10* while adjusting for other variables. Data concerning significance level and effect size of all independent parameters in the secondary ANCOVA with *DF* separated from *VF*.

Table S3.

Source	df	F	Sig.	Partial Eta Squared
Corrected Model	11	2.87	0.004	0.34
Goup	3	5.6	0.002	0.21
Sex	1	0.27	0.60	0.00
Age	1	0.37	0.54	0.01
Processing speed	1	0.1	0.75	0.00
Attention	1	0.64	0.43	0.01
Working memory	1	0.00	0.93	0.00
Short-term memory	1	0.22	0.64	0.00
Inhibition	1	6.55	0.013	0.096
Verbal Fluency	1	7.08	0.01	0.10

Table S3. ANCOVA-analysis showing the effect of *VF* on the score of *Sick-leaveLog10* while adjusting for other variables. Data concerning significance level and effect size of all independent parameters in the secondary ANCOVA with *VF* separated from *DF*.

Table S4.

	DF1	***DF2***	***DF3***
Pearson's r / p-value	-0.135 / 0.253	-0.291 / 0.012	-0.223 / 0.056
	VF1	***VF2***	***VF3***
Pearson's r / p-value	-0.277 / 0.017	-0.177 / 0.132	-0.233 / 0.046

Table S4. The independent contribution of *DF1-3* and *VF1-3* to sick leave in subjects who had at least one day of sick leave (n=74). *Sick Leave log 10* was used as outcome variable due to non-normal distribution in raw data.