

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/7970809>

# The effect of office concepts on worker health and performance: A systematic review of the literature

Article in *Ergonomics* · March 2005

DOI: 10.1080/00140130512331319409 · Source: PubMed

CITATIONS

255

READS

1,503

4 authors:



**E. M. de Croon**

Onderzoeksraad voor Veiligheid

31 PUBLICATIONS 1,585 CITATIONS

[SEE PROFILE](#)



**Judith K Sluiter**

Academisch Medisch Centrum Universiteit van Amsterdam

368 PUBLICATIONS 7,045 CITATIONS

[SEE PROFILE](#)



**P Paul F M Kuijter**

Amsterdam University Medical Centers - location AMC

310 PUBLICATIONS 3,030 CITATIONS

[SEE PROFILE](#)



**Monique H W Frings-Dresen**

University of Amsterdam

466 PUBLICATIONS 8,642 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



SPIKE the PCHA - Overuse injury of the Posterior Circumflex Humeral Artery in elite volleyball players [View project](#)



Low back pain related occupational disease [View project](#)

# The effect of office concepts on worker health and performance: a systematic review of the literature

EINAR M. DE CROON\*, JUDITH K. SLUITER,  
P. PAUL F.M. KUIJER and MONIQUE H.W. FRINGS-DRESEN

Coronel Institute for Occupational and Environmental Health, Academic Medical Center, Research Institute Amsterdam Center for Health and Health Care Research (AmCOGG), Amsterdam, The Netherlands

Conventional and innovative office concepts can be described according to three dimensions: (1) the office location (e.g. telework office versus conventional office); (2) the office lay-out (e.g. open lay-out versus cellular office); and (3) the office use (e.g. fixed versus shared workplaces). This review examined how these three office dimensions affect the office worker's job demands, job resources, short- and long-term reactions. Using search terms related to the office concept (dimensions), a systematic literature search starting from 1972 was conducted in seven databases. Subsequently, based on the quality of the studies and the consistency of the findings, the level of evidence for the observed findings was assessed. Out of 1091 hits 49 relevant studies were identified. Results provide strong evidence that working in open workplaces reduces privacy and job satisfaction. Limited evidence is available that working in open workplaces intensifies cognitive workload and worsens interpersonal relations; close distance between workstations intensifies cognitive workload and reduces privacy; and desk-sharing improves communication. Due to a lack of studies no evidence was obtained for an effect of the three office dimensions on long-term reactions. The results suggest that ergonomists involved in office innovation could play a meaningful role in safeguarding the worker's job demands, job resources and well-being. Attention should be paid, in particular, to effects of workplace openness by providing acoustic and visual protection.

*Keywords:* Office; Health; Performance

---

\*Corresponding author. Email: e.m.decroon@amc.uva.nl

## 1. Introduction

With the introduction of Information and Communication Technology and more flexible ways of organizing work processes, the work environment of office workers has changed substantially in the last decades. The changing nature of the office worker's environment is exemplified by the growing number of organizations that move from conventional offices with fixed workplaces to more open and transparent offices with shared workplaces (Vos and Van der Voordt 2002). Another example is the increasing number of organizations that allow office workers to work at home as a teleworker (Standen *et al.* 1999).

The introduction of innovative office concepts may allow organizations to save office space, reduce general and technical service costs and increase flexibility of office use. From a cost-efficiency point of view, therefore, the introduction of these office concepts seems advantageous. However, new office concepts may affect office worker health as well as office worker performance. An office concept characterized by an open and transparent lay-out, may, for instance, increase distraction and irritability and, as a consequence, threaten the health and performance of the office worker in the longer term. Potential effects of office concepts on health and performance, therefore, should also be considered in the development and introduction of new office concepts (Pullen and Bradley 2004).

## 2. Conceptual model

Building on architectural nomenclature (Vos *et al.* 1999), social relations approach, cognitive overload theory (Desor 1972; Geen and Gange 1977; Oldham *et al.* 1991; Evans and Lepore 1992), privacy theory (Sundstrom *et al.* 1980), the demand-resources theory of occupational stress (Demerouti *et al.* 2001) and the model of workload and capacity (Van Dijk *et al.* 1990) a general conceptual model was constructed for this study. This model depicts the relationship between office concepts and worker health and performance (see figure 1). For the purpose of this study, office concepts are defined in the model by three office dimensions, namely, the office location, the office lay-out and the office use (albeit the relevance of other office aspects such as office furniture and office climate is recognized). According to the model, office concepts in terms of these three dimensions influence work conditions in terms of job demands and job resources. These work conditions, in turn, may result in (un)favourable psychophysiological short-term reactions. Office concepts may also influence these short-term reactions independently of job demands and job resources. In the longer run, short-term reactions may affect office worker health and performance, termed long-term reactions in the model. The concepts of the model are described below.

### 2.1. Office concepts: location, lay-out and use

Three dimensions can be used to describe office concepts (Vos *et al.* 1999): the office location; the office lay-out; and the office use. The *office location* refers to the place at which the office worker carries out his/her activities. The office worker may work in the conventional office, or he/she may work in the telework office at home. The *office lay-out* refers to the arrangement of workplaces and type of boundaries in an office (Oldham *et al.* 1995). Two core features of the office lay-out are included in the conceptual model, namely, the workplace openness and the distance between workstations. The *office use* refers to the manner in which workplaces are assigned to office workers. One single

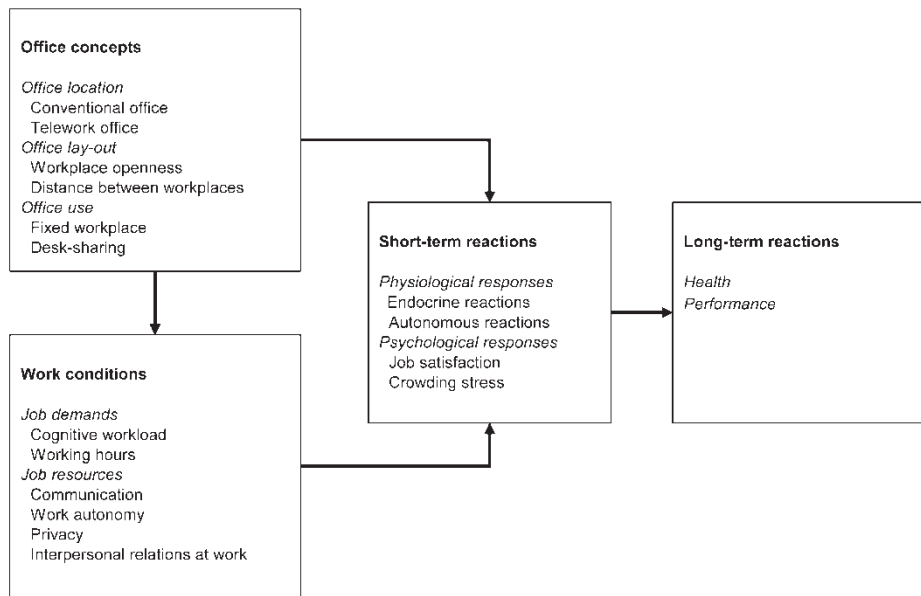


Figure 1. Conceptual model that depicts the hypothesized relation from office concepts in terms of office location, office lay-out and office use (via) demands and resources to short- and long-term reactions.

workplace may be assigned to one single office worker (i.e. the fixed workplace), or one workplace may be assigned to a range of office workers, hereafter termed desk-sharing.

## 2.2. Work conditions: job demands and job resources

*Job demands* are work conditions that require physical, mental or emotional effort (Demerouti *et al.* 2001). Office concepts may impact on several job demands. In the model two demands are distinguished: (a) cognitive workload, i.e. the extent to which office stimuli, such as noise, place an elevated demand on cognitive-attentional processes; and (b) working hours, such as irregular working hours due to desk-sharing. *Job resources* are work conditions that are supportive in achieving work goals, reduce job demands at the associated physiological and psychological costs, or stimulate personal growth and development. Office concepts may also influence job resources. The conceptual model differentiates four resources: (a) communication (e.g. desk-sharing may stimulate communication); (b) work autonomy (e.g. teleworking may increase autonomy over work scheduling); (c) psychological privacy (e.g. an open office may reduce psychological privacy); and (d) interpersonal relations at work (e.g. teleworking may reduce social support from co-workers).

## 2.3. Short-term reactions

According to the conceptual model, office concepts may directly or indirectly, via job demands and job resources, result in physiological and psychological short-term reactions, such as crowding stress, i.e. the psychological state of inadequacy of space (Stokols 1972), occupationally induced fatigue, job satisfaction, the excretion of cortisol and increased levels of blood pressure.

## **2.4. Long-term reactions**

Accumulation of short-term reactions may, in the long term, result in more serious reactions. These long-term reactions include decreased performance (Cotton and Hart 2003) and negative health outcomes, such as psychosomatic health complaints including chronic fatigue, burnout and musculoskeletal disorders (De Lange *et al.* 2002; Sluiter *et al.* 2003).

## **3. Research aims**

Narrative reviews of research on office effects have provided us with useful information (Wineman 1982; Davis 1984; Oldham *et al.* 1995; Gifford 1997; Standen *et al.* 1999; Brennan *et al.* 2002). However, to the authors' knowledge, an updated review in which the evidence is searched and synthesized in a systematic and critical manner has not been conducted. This study, therefore, systematically reviewed the scientific literature on effects of office concepts. To this end, the relations depicted in the conceptual model were translated into three research questions.

1. What is the effect of office location on work conditions (demands and resources), short- and long-term reactions?
2. What is the effect of office lay-out on work conditions (demands and resources), short- and long-term reactions?
3. What is the effect of office use on work conditions (demands and resources), short- and long-term reactions?

## **4. Methods**

### **4.1. Literature search and selection**

A literature search was conducted with a range of search terms in the title and/or abstract (see table 1). The search was conducted in: 1) Picarta (Dutch research reports) 2); OSHROM (1970–2003); 3) PsycINFO (1970–2003); 4) Biological abstracts (1972–2003); 5) Sociological abstracts (1970–2003); 6) Embase (1980–2003); and 7) Ergonomic Abstracts (1985–2003). Furthermore, to find additional publications a reference check of the identified studies was performed and conversations with four Dutch experts in the field of office innovation were conducted.

Study selection was carried out in two stages. In the first stage, studies were included on the basis of title and abstract using four inclusion criteria: (a) original study (no review or opinion article); (b) the study examines office location, office lay-out or office use as independent variables; (c) the study is conducted among individuals who perform paid office work in an office environment; and (d) analogous with the conceptual model, the study examines work conditions, short- or long-term reactions as dependent variables. In the second stage, studies were included on the basis of the whole manuscript using the same four criteria.

### **4.2. Methodological quality assessment**

Using generally accepted criteria as the point of departure (Altman 2001), the quality of the included studies was evaluated on the basis of: (a) the response percentage (> 50%):

Table 1. Terms in title or summary used for the search.

Activity-related office	Landscape office	Virtual $\cap$ office
Lean office	Office renovation	Telework $\cap$ office
Clean desk	New office	Working at home $\cap$ office
Cocon <sup>a</sup> concept	Innovative workplace	Private $\cap$ office
Cocon office	New office layout	Open(ness) $\cap$ office
Combi-office	Non territorial office	Closed $\cap$ office
Concentration workplace	Non-territorial office	Density $\cap$ office
Conventional office	Open office	Dense $\cap$ office
Desk-sharing	Open plan office	Crowding $\cap$ office
Wireless office	Team office	Enclosures $\cap$ office
Dynamic <sup>b</sup> office	Traditional office	Spatial $\cap$ office
Experimental office	Variety office	Boundaries $\cap$ office
Flexible office	Office transformation	Distance $\cap$ office
Flexible workplace	Virtual office	Accessibility $\cap$ office
Shared office	Innovative office	Visibility $\cap$ office
Group office	Workplace innovation	Partitions $\cap$ office
Hotel office	Shared workplace	Noise $\cap$ office
Innovative office	Office innovation	Privacy $\cap$ office
Innovative workplace concepts		Flexible $\cap$ office

*Note.* <sup>a</sup>Cocon office is derived from the terms communication and concentration and is characterized by separate and small workstations destined for carrying out individual tasks and a large communal room reserved for consultations. <sup>b</sup>Dynamic office concerns an office concept that allows office workers to search for a workstation that is fitted to the very task at hand. At office management the office worker may book a workstation in advance.

(b) the adequacy of the statistical tests that were used; and (c) the quality of the study design (see Table 2 for an explanation). Studies were classified as high quality studies when they met all three quality criteria. Studies that met one or two quality criteria were classified as medium quality studies. Studies that did not meet any quality criterion were labelled low quality studies and were excluded from further review in spite of their preceding inclusion.

#### 4.3. Synthesis of the evidence

On the basis of the quality and consistency of the findings in the literature (Ariëns *et al.* 2001; Lievense *et al.* 2002), the information on office effects was synthesized into four levels of evidence: (1) *insufficient evidence*: less than three studies are available; (2) *limited evidence*: consistent findings in one or two high-quality studies and at least two medium quality studies; (3) *strong evidence*: consistent findings in at least three high quality studies; and (4) *inconsistent evidence*: the remaining cases. It should be noted that only statistically significant findings were taken into account in the evidence synthesis.

## 5. Results

The search in the databases and the reference lists, as well as the conversations with the experts, resulted in 1091 publications. After the first inclusion stage, 80 publications were withheld. After the second inclusion stage, 49 of these 80 publications remained in the study for review.

Table 3 gives information on the independent and dependent variables, the country in which the study was conducted, the occupational setting, the response percentage, the

Table 2. Description and evaluation of the four study designs

Type of design	Description	Evaluation (0–1)
Laboratory design	Design in which a specific office environment is simulated and potential effects on work conditions, health and well-being are examined under controlled conditions	1
Prospective field design	Design in which work conditions, health and well-being of the same office workers are observed before and after an office transformation	1
Retrospective field design	Design in which office workers who occupy a new office are asked to compare work conditions, health and well-being in the current office environment with work conditions, health and well-being of their former office	0
Cross-sectional field design	Design in which work conditions, health and well-being of two groups of office workers in different office environments are compared	0

*Note.* 0 = design is of low to medium quality; 1 = design is of high quality.

adequacy of statistical testing, the study design and the quality rating. Inspection of table 3 reveals that twelve studies met all three quality criteria (high quality studies); 35 studies met one or two criteria (medium quality studies); and two studies met no criteria (excluded low quality studies). Three, seven and 37 studies investigated the office location, the office lay-out and the office use, respectively, as the independent variable. Furthermore, the effect on work conditions, short- and long-term reactions was examined in 25, 26 and 17 studies, respectively. Please note that several studies examined more than one dependent variable.

### 5.1. Effects of office location on work conditions and short- and long-term reactions

**5.1.1. Effect of office location on work conditions.** Three studies (references 1, 2, 3 in table 3) examined the effect of office location, namely, teleworking at home, on work conditions. One study (reference 3 in table 3) established no effect of teleworking on working hours, communication, autonomy and interpersonal relations. The second study (reference 2 in table 3) showed that teleworking was associated with more overwork as compared to working in the conventional office. Furthermore, this study demonstrated that teleworkers perceive more work autonomy as compared to office workers in the conventional office. The third study (reference 1 in table 3) did not show evidence of an effect of teleworking on working hours and interpersonal relations. In short, there is *insufficient evidence* to conclude about the effect of teleworking on work conditions.

**5.1.2. Effect of office location on short-term reactions.** Two studies (references 2, 3 in table 3) looked into the effect of teleworking at home on short-term reactions. One study (reference 3 in table 3) failed to find an effect of teleworking on job satisfaction. The other study (reference 2 in table 3) found that, as compared to working in the conventional office, teleworking at home slowed down adrenaline recovery after work. In short, there is *insufficient evidence* to make a conclusion about the effect of office location on short-term reactions.

**5.1.3. Effects of office location on long-term reactions.** One study (reference 2 in table 3) investigated the association between teleworking at home and performance. This study

Table 3. Description of the 49 studies.

Reference number (reference)	Setting of study population	Country	Follow-up in months	N	Independent variable	Dependent variable			Response	Statist. test	Study design	Total score	Quality
						W	S	L					
1. (Hill <i>et al.</i> 1998)	Marketing	US	–	246	Location	✓		✓	60%	1	CFD	2	MQ
2. (Lundberg and Lindfors 2002)	Government	Sweden	<1	26	Location	✓	✓		46%	1	PFD	2	MQ
3. (Olson 1989)	IT	US	6	32	Location	✓	✓		100%	1	PFD	3	HQ
4. (Banburry and Berry 1997)	Clerical	UK	–	48	Lay-out			✓	100%	1	LAB	3	HQ
5. (Banburry and Berry 1998)	Clerical	UK		48	Lay-out			✓	100%	1	LAB	3	HQ
6. (Becker <i>et al.</i> 1983)	University	US	–	100	Lay-out	✓			97%	1	CFD	2	MQ
7. (Block 1989)	Clerical	US		169	Lay-out	✓	✓		100%	1	LAB	3	HQ
8. (Brasche <i>et al.</i> 2001)	Diverse	Germany	NA		Lay-out			✓	70%	1	CFD	2	MQ
9. (Brennan <i>et al.</i> 2002)	Petrol company	Canada	6	21	Lay-out	✓	✓	✓	26%	1	PFD	2	MQ
10. (Brookes 1972)	Retail firm	US	9	100	Lay-out	✓			83%	1	PFD	3	HQ
11. (Carlopio and Gardner 1992)	Bank	Australia	–	228	Lay-out	✓	✓		60%	1	CFD	2	MQ
12. (Cosijn and Den Hertog 1972)	Electronics	Netherlands	36	365	Lay-out	✓			82%	0	RFD	1	MQ
13. (Crouch and Nimran 1989)	Government	Australia	–	51	Lay-out	✓		✓	29%	1	CFD	1	MQ
14. (Duvall-Early and Benedict 1992)	Secretary	US	–	130	Lay-out	✓			65%	1	CFD	2	MQ
15. (Evans and Johnson 2000)	Clerical	US	–	40	Lay-out			✓	100%	1	LAB	3	HQ
16. (Fried 1990)	University	US	–	152	Lay-out			✓	62%	1	CFD	2	MQ
17. (Fried <i>et al.</i> 2001)	University	US	–	93	Lay-out	✓	✓		NA	1	CFD	1	MQ
18. (Hedge 1984)	Government	US	–	1,332	Lay-out	✓		✓	65%	1	CFD	2	MQ
19. (Jaakkola and Heinonen 1995)	Government	Finland	–	122	Lay-out			✓	71%	1	CFD	2	MQ
20. (Keller 1986)	R&D	US	–	221	Lay-out			✓	90%	1	CFD	2	MQ
21. (Kupritz 1998)	Designers	US	–	89	Lay-out	✓			100%	1	CFD	2	MQ
22. (Kurvers <i>et al.</i> 2001)	NA	US	–	7,822	Lay-out			✓	NA	0	CFD	1	MQ
23. (Marans and Yan 1989)	Diverse	Australia	–	1,000	Lay-out			✓	80%	0	CFD	1	MQ
24. (O'Brien and Pembroke 1982)	Government	Australia	–	195	Lay-out	✓	✓		76%	1	CFD	2	MQ
25. (O'Neill 1994)	Diverse	US	–	541	Lay-out	✓	✓	✓	77%	1	CFD	2	MQ
26. (Oldham and Brass 1979)	Publisher	US	5	128	Lay-out	✓	✓		91%	1	PFD	3	HQ
27. (Oldham and Rotchford 1983)	University	US	–	114	Lay-out	✓	✓		100%	1	CFD	2	MQ
28. (Oldham and Fried 1987)	University	US	24	109	Lay-out		✓	✓	96%	1	PFD	3	HQ

(continued)



Table 3 (continued)

Reference number (reference)	Setting of study population	Country	Follow-up in months	N	Independent variable	Dependent variable			Response	Statist. test	Study design	Total score	Quality
						W	S	L					
29. (Oldham 1988)	Insurance	US	3	65	Lay-out	✓	✓	✓	51%	1	PFD	3	HQ
30. (Oldham <i>et al.</i> 1991)	Government	US	–	298	Lay-out	✓	✓	✓	100%	1	CFD	2	MQ
31. (Rishi <i>et al.</i> 2000)	Bank	India	–	85	Lay-out	✓	✓		100%	1	CFD	2	MQ
32. (Sundstrom <i>et al.</i> 1980)	Diverse	US	–	213	Lay-out	✓	✓	✓	74%	1	CFD	2	MQ
33. (Sundstrom <i>et al.</i> 1982b)	Diverse	US	–	228	Lay-out	✓	✓		76%	1	CFD	2	MQ
34. (Sundstrom <i>et al.</i> 1982a)	NA	US	2	70	Lay-out	✓			54%	1	PFD	3	HQ
35. (Sutton and Rafaeli 1987)	University	US	–	109	Lay-out		✓	✓	100%	1	CFD	2	MQ
36. (Szilagyi and Holland 1980)	Petrol company	US	4	96	Lay-out	✓	✓		100%	1	PFD	3	HQ
37. (Wollmann <i>et al.</i> 1994)	University	US	–	293	Lay-out		✓		59%	1	CFD	2	MQ
38. (Zahn 1992)	Industry	US	–	45	Lay-out	✓			48%	1	CFD	1	MQ
39. (Zalesny and Farace 1987)	Government	US	11	247	Lay-out	✓			52%	1	PFD	3	HQ
40. (Zhou <i>et al.</i> 1998)	University	US	–	75	Lay-out	✓			62%	1	CFD	2	MQ
41. (Allen and Gerstberger 1973)	Product engineers	US	12	10	Use	✓	✓	✓	41%	1	PFD	2	MQ
42. (Barten 2001)	Bank	Netherlands	11	72	Use	✓	✓		33%	0	RFD	0	LQ
43. (Beunder 2000)	Bank	Netherlands	12	30	Use	✓		✓	75%	0	RFD	1	MQ
44. (Boerstra and Raue 2000)	Government	Netherlands	6	19	Use	✓			58%	0	RFD	1	MQ
45. (De Jonge and Rutte 1999)	Insurance	Netherlands	24	122	Use	✓	✓	✓	20%	1	PFD	2	MQ
46. (Heerink and Vermeulen 2001)	Accountancy	Netherlands	NA	211	Use	✓	✓	✓	53%	0	RFD	1	MQ
47. (Van den Brink 2000)	Bank	Netherlands	13	159	Use	✓			63%	0	RFD	1	MQ
48. (Van Wijk 1999)	NA	Netherlands	5	257	Use	✓			30%	0	RFD	0	LQ
49. (Vos and Dewulf 1998)	Government	Netherlands	24	152	Use	✓			66%	0	RFD	1	MQ

*Note.* NA = information is not available; Follow-up = duration of follow-up in months; N = number of participants; Independent variable: location = workplace location; lay-out = workplace lay-out; use = workplace use; Dependent variable: W = work conditions (job demands or job resources); S = short-term reactions; L = long-term reactions; Response = percentage of office workers who participated; Statist. test = the adequacy of the statistical test that was used in the study (0 = insufficient; 1 = sufficient); Study design: LAB = laboratory design; PFD = prospective field design; RFS = retrospective field design; CFD = cross-sectional field design; Total score = the number of quality criteria that were fulfilled (0–3); Quality: HQ = high-quality study, MQ = medium-quality study, LQ = low-quality study (excluded from the review).

failed to establish an association between teleworking and performance. Thus, there is *insufficient evidence* to conclude on the effect of office location on long-term reactions.

## 5.2. Effects of office lay-out on work conditions and short- and long-term reactions

**5.2.1. Effects of office lay-out on work conditions.** Twenty-four studies examined the effect of workplace openness, or distance between workplaces on cognitive workload, communication, interpersonal relations, autonomy, or psychological privacy (references 6, 7, 9–14, 17, 18, 21, 24–27, 29, 31–34, 36, 38–40 in table 3). Table 4 indicates there is *strong evidence* that working in open workplaces reduces the office worker's psychological privacy and there is *limited evidence* that working in open workplaces intensifies cognitive workload and worsens interpersonal relations. As is also shown in table 4, *inconsistent*

Table 4. Results of the synthesis of evidence with regard to the effect of office lay-out (workplace openness and distance between workstations) on work conditions (cognitive workload, communication, interpersonal relations, autonomy and privacy).

	Studies, first author (reference number)	Association (reference number)	Evidence (direction)
<b>Effect of workplace openness on:</b>			
Cognitive workload	2 HQ: Block (7), Oldham (26) 5 MQ: Becker (6), Crouch (14), Kupritz (21), O'Neil (25), Oldham (27)	Positive (7, 26) No (25, 27); Positive (6, 14, 21)	Limited (positive)
Communication	3 HQ: Oldham (26), Sundstrom (34), Zalesny (39) 3 MQ: Cosijn (12), O'Neil (25), Oldham (27)	No (26, 34); Negative (39) No (27); Negative (12, 25)	Inconsistent
Interpersonal relations	1 HQ: Oldham (26) 3 MQ: Brennan (9), Fried (17), Oldham (27)	Negative (26) No (17); Negative (9, 27)	Limited (negative)
Autonomy	2 HQ: Oldham (29), Zalesny (39) 2 MQ: Oldham (27)	No (29, 39) Negative (27)	Inconsistent
Psychological privacy	4 HQ: Brookes (10), Oldham (29), Sundstrom (34), Zalesny (39) 10 MQ: Becker (6), Carlopio (11), Crouch (12), Duvall-Early (14), Kupritz (21), O'Neil (25), Oldham (27), Rishi (31), Sundstrom (32, 33)	Negative (10, 29, 34, 39) Negative (6, 11, 12, 14, 21, 25, 27, 31, 32, 33)	Strong (negative)
<b>Effect of distance between work stations on:</b>			
Cognitive workload	2 MQ: O'Neil (25), Oldham (27) 1 HQ: Oldham (29)	Negative (25, 27) Negative (29)	Limited (negative)
Communication	1 HQ: Szilagyi (36) 2 MQ: Oldham (27), Zahn (38)	Negative (36) No (27); Negative (38)	Inconsistent Inconsistent
Autonomy	1 HQ: Szilagyi (36) 1 MQ: Oldham (27)	Negative (36) No (27)	Inconsistent
Psychological privacy	1 HQ: Oldham (29) 4 MQ: Duvall-Early (14), Oldham (27), Rishi (31), Sundstrom (32)	Positive (29) No (32); Positive (14, 27, 31)	Limited (positive)

Note. HQ = high-quality study; MQ = medium-quality study.

evidence was found for an effect of workplace openness on communication and autonomy. Moreover, there is *limited evidence* that a close distance between workplaces intensifies the office worker's cognitive workload and reduces his/her psychological privacy. Finally, there is *inconsistent evidence* for an effect of distance between workstations on communication and autonomy.

**5.2.2. Effects of office lay-out on short-term reactions.** Twenty-one studies examined the effect of workplace openness or distance between workstations on short-term reactions (references 7, 9, 11, 15–17, 20, 23–33, 35–37 in table 3). From table 5 it can be seen there is *strong evidence* that working in open workplaces reduces job satisfaction. Table 5 also shows there is inconsistent evidence for an effect of close distance between workstations on job satisfaction and for an effect of workplace openness and distance between workstations on crowding stress.

**5.2.3. Effects of office lay-out on long-term reactions.** Sixteen studies examined the effect of workplace openness or distance between workstations on long-term reactions (references 4, 5, 8, 9, 13, 16, 18, 19, 20, 22, 25, 28–30, 32, 35 in table 3). The evidence synthesis shows there is inconsistent evidence for an effect of workplace openness and distance between work stations on performance and health.

### 5.3. Effects of office use on work conditions and short- and long-term reactions

**5.3.1. Effects of office use on work conditions.** Seven medium quality studies examined the effect of office use on work conditions (references 41, 43–47, 49 in table 3). Synthesis of the evidence shows there is *limited evidence* that desk-sharing improves communication

Table 5. Results of the synthesis of evidence with regard to the effect of office lay-out (workplace openness and distance between workstations) on short-term reactions (crowding stress and job satisfaction).

	Studies, first author (reference number)	Association (reference number)	Evidence (direction)
<b>Effect of workplace openness on:</b>			
Crowding stress	1 HQ: Oldham (29)	Positive (29)	Inconsistent
	5 MQ: Carlopio (11), Oldham (27), Rishi (31), Sundstrom (32), Zhou (34)	No (11, 27, 34); Positive (31, 32)	
Job satisfaction	4 HQ: Block (7), Oldham (26, 28, 29)	Negative (7, 26, 28, 29)	Strong (negative)
	6 MQ: Oldham (27, 30), Rishi (31), Sundstrom (32, 33), Sutton (35)	No (27, 32, 33); Negative (30, 31, 35)	
<b>Effect of distance between work stations on:</b>			
Crowding stress	1 HQ: Oldham (29)	Negative (29)	Inconsistent
	5 MQ: O'Brien (24), Oldham (27), Rishi (31), Sundstrom (32), Zhou (34)	No (24, 31, 32, 34); Negative (27)	
Job satisfaction	2 HQ: Oldham (29), Szilagyi (36)	Positive (29), Negative (36)	Inconsistent
	9 MQ: Fried (17), Keller (20), O'Brien (24), Oldham (27, 30), Rishi (31), Sundstrom (32, 39), Sutton (35)	No (20, 27, 31, 32, 39); Positive (17, 24, 30, 35)	

Note. HQ = high-quality study; MQ = medium-quality study.

between office workers. In addition, *inconsistent evidence* was found that desk-sharing intensifies cognitive workload.

**5.3.2. Effects of office use on short-term reactions.** Three studies investigated the effect of office use, i.e. desk-sharing, on short-term reactions (references 41, 45, 46 in table 3). Due to the small number of studies the evidence is *insufficient* to make inferences about the effect of office use on short-term reactions.

**5.3.3. Effects of office use on long-term reactions.** Four studies examined the effect of office use, namely, desk-sharing, on long-term reactions (references 41, 43, 45, 46 in table 3). Due to *insufficient evidence* no inferences about the effect of desk-sharing on long-term reactions can be made.

## 6. Discussion

### 6.1. Effects of office innovation

This review failed to provide evidence for an effect of office location, namely, teleworking at home, on work conditions, short- and long-term reactions. In contrast, evidence was provided for an effect of office lay-out on work conditions and short-term reactions. In particular, strong evidence was found that working in open workplaces reduces the office worker's privacy and job satisfaction. Also, limited evidence was found that close distance between workstations intensifies cognitive workload and reduces psychological privacy. In accordance with the conceptual model (see figure 1), therefore, office concepts do affect the office worker's job demands, job resources and short-term reactions. More specifically, consistent with overload theory (Desor 1972; Oldham and Fried 1987), open workplaces and high-density offices increase cognitive workload, it is thought, due to too many people and interactions and too close proximity to others. Consequently, office workers have difficulty concentrating, react negatively to interactions and become dissatisfied with their job. Furthermore, compatible with privacy theory (Sundstrom *et al.* 1980), the lack of acoustic and visual isolation in open workplaces diminishes the control over interaction with others and hinders workers in discussing personal topics in confidence.

Also in agreement with the conceptual model, office use, in terms of desk-sharing, was found to stimulate communication between office workers. In particular, the evidence synthesis provided limited evidence that desk-sharing improves this job resource. Presumably, office workers who share desks need to change workplaces repeatedly. This increases the opportunity to interact and, as a consequence, improves communication (Vos and Van der Voordt 2002).

In contrast to the conceptual model's propositions, inconsistent evidence was provided for the effect of office lay-out on communication, autonomy, crowding stress, performance and health. Possibly, person-, work-, or environment-related variables moderate effects of the office lay-out. Indeed, person-related variables such as low need for privacy (Oldham 1988), high screening ability (Fried 1990; Oldham *et al.* 1991) and low organizational tenure (Fried *et al.* 2001) have been found to buffer harmful office effects. Furthermore, work-related variables, such as low task complexity (Block 1989), and environment-related variables, such as favourable lighting and air conditions (Hedge 1984; Adams and Zuckerman 1991), may protect office workers from negative office lay-out effects. Integration of these variables into the conceptual model may improve its predictive validity.

## 6.2. *Scientific considerations*

Four aspects of this review should be commented upon to appreciate the practical implications of the findings. First, as mentioned briefly in the introduction, other aspects of the office plan may influence office worker health and performance. These aspects include characteristics of desks and chairs (de Looze *et al.* 2004), computers, monitors and keyboards (Briner and Hockey 1994; Hedge and Powers 1995), lighting conditions (Hedge 2000), colour and material use (Carlopio 1996; Gifford 1997), thermal conditions (Vasmatzidis *et al.* 2002) and the indoor air quality (Menzies and Bourbeau 1997; Kolstad *et al.* 2002; Burge 2004). To obtain a full picture of office effects, these characteristics should also be considered.

Second, although a large number of publications about effects of office concepts were found, the number of scientific studies with a prospective or laboratory design and adequate response was small. This restricted the opportunity to make inferences about several hypothesized office effects. Research that addresses the effects of office location (i.e. telework) and office use (i.e. desk-sharing), as well as research that examines health effects of office innovation in particular, is scarce. Considering the popularity of telework and desk-sharing and the high prevalence of stress-related health complaints such as fatigue and musculoskeletal complaints among office workers, this gap in knowledge is remarkable.

Third, this review examined the effect of innovative offices on work conditions and health and performance of office workers without taking the implementation process into account. Conversations with experts involved in the development of new office concepts, however, reveal that office concepts are often implemented without the participation of the office worker. Research has demonstrated that low participation during implementation of innovations may negatively affect the worker's attitude (Baruch and Hind 2003). Presumably, the involvement of office workers will promote the successful implementation of innovative offices.

Fourth, the integration of the study quality in the synthesis of the evidence (Slavin 1995) allowed more weight to be given to results obtained in high-quality studies when reaching conclusions, as compared to results obtained in medium quality studies. The best-evidence-methodology, therefore, is considered a strong aspect of this review.

## 6.3. *Practical implications*

The findings of this review carry practical implications for ergonomists involved in the development and implementation of innovative offices. First, the unfavourable effect of workplace openness implies that, to safeguard the well-being of the office worker, innovative offices should provide sufficient shelter from unwanted acoustic and visual stimuli. To this end, innovative offices should be supplied with an adequate number of enclosed, sound-insulated workstations. In addition, tall, enclosed or frosted glass sound-insulating partitions between open workplaces, textile floor covering, acoustic ceiling tiles and printer cabinets might be applied for this purpose. Second, the moderating effect of person-, work- and environment-related variables implies that detrimental office effects might be diminished by the application of measures directed at these variables. Ergonomists might, for instance, prevent unfavourable effects of open and crowded offices by improving lighting and climate conditions. In addition, attention might be paid to the workplace lay-out of high tenure office workers who have a higher need for privacy and low screening-ability, and are engaged in complex work. Third, the observed limited

evidence for an effect of desk-sharing on communication suggests that companies might improve organizational effectiveness by application of this office concept.

#### 6.4. Conclusions

Strong evidence was established that working in open workplaces reduces the office worker's psychological privacy and job satisfaction. Additionally, some limited evidence was found that: (a) working in open workplaces intensifies cognitive workload and worsens interpersonal relations; (b) a close distance between workstations intensifies cognitive workload and reduces the office worker's psychological privacy; and (c) desk-sharing improves communication. These findings indicate that innovative offices may affect the organization's cost-efficiency as well as the office worker's work conditions and well-being. Therefore, the effect of innovative offices on the office worker's work conditions and well-being should be considered during the development and introduction of innovative offices.

#### Acknowledgements

We would like to thank Jaap Hanekamp of the Heidelberg Appeal Netherlands Foundation, Chris Kuiper, Lector at the Institute for Work and Health, Academy of Rotterdam and Wim Pullen, Managing Director of the Center for People and Buildings at the University of Delft for their support during this study. We are also grateful to John Bergs of BenR advisers, Atze Boerstra of Boerstra Indoor Climate Consultancy, Ernst Koningsveld of TNO Work and Employment, Professor Annelies van Bronswijk of the University of Eindhoven and Theo Van der Voordt of the Department of Architecture at the University of Delft for their help during the literature search.

#### References

- ADAMS, L. and ZUCKERMAN, D., 1991, The effect of lighting conditions on personal space requirements. *The Journal of General Psychology*, **118**, pp. 335–340.
- ALLEN, T. J. and GERSTBERGER, P. G., 1973, A field experiment to improve communications in a product engineering department: the non-territorial office. *Human Factors*, **15**, pp. 487–498.
- ALTMAN, D. G., 2001, Systematic reviews of evaluations of prognostic variables In *Systematic Reviews in Health Care*, M. Egger, G. D. Smith and D. G. Altman (Eds), pp. 228–247. (London: BMJ Publishing Group)
- ARIËNS, G. A. M., VAN MECHELEN, W., BONGERS, P. M., BOUTER, L. M. and VAN DER WAL, G., 2001, Psychosocial risk factors for neck pain: a systematic review. *American Journal of Industrial Medicine*, **39**, pp. 180–193.
- BANBURY, S. and BERRY, D. C., 1997, Habituation and dishabituation to speech and office noise. *Journal of Experimental Psychology*, **3**, pp. 181–195.
- BANBURY, S. and BERRY, D. C., 1998, Disruption of office-related tasks by speech and office noise. *British Journal of Psychology*, **89**, pp. 499–517.
- BARTEN, E., 2001, *Fortezza. De Effecten in Beeld*. (Fortezza, evaluation of the implementation of desk-sharing at ABN/AMRO) (Amsterdam: ABN AMRO, DOI&H Concern huisvesting en Vastgoed, Taskforce flexibel Werken).
- BARUCH, Y. and HIND, P., 2003, Perceptual motion in organizations: effective management and the impact of the new psychological contracts on "Survivor Syndrome", *European Journal of Work and Organizational Psychology*, **8**, pp. 295–306.
- BECKER, F. D., GIELD, B., GAYLIN, K. and SAYER, S., 1983, Office design in a community college: effect on work and communication patterns, *Environment and Behavior*, **15**, pp. 699–726.
- BEUNDER, M., 2000, *Wisselwerken Interne Controle/RB. De Effecten in Kaart*. (Evaluation of desk-sharing at ABN/AMRO, department internal affairs and control) (Amsterdam: ABN AMRO, DOI&H Concern huisvesting en Vastgoed, Taskforce flexibel Werken).

- BLOCK, L. K., 1989, Performance and satisfaction in private versus non-private work settings. *Environment and Behavior*, **3**, pp. 277–279.
- BOERSTRA, A. C. and RAUE, A. K., 2000, *Evaluatie Herinrichting PO&I Departementsgebouw Ministerie van Sociale Zaken en Werkgelegenheid* (Evaluation of the implementation of desk sharing at the Personnel Department of the Ministry of Social Affairs and Employment) (Den Haag: Ministerie van Sociale Zaken en Werkgelegenheid).
- BRASCHE, S., BULLINGER, M., MORFELD, M., GEBHARDT, H. J. and BISCHOF, W., 2001, Why do women suffer from Sick Building Syndrome more often than men? Subjective higher sensitivity versus objective causes. *Indoor Air*, **11**, pp. 217–222.
- BRENNAN, A., CHUGH, J. S. and KLINE, T., 2002, Traditional versus open office designs: a longitudinal study. *Environment and Behavior*, **34**, pp. 279–299.
- BRINER, R. and HOCKEY, R. J. 1994, Operator stress and computer-based work. In *Causes, Coping and Consequences of Stress at Work*, C. L. Cooper and R. Payne (Eds), pp. 115–140. (Chichester: Wiley).
- BROOKES, M. J., 1972, Office landscape: does it work? *Applied Ergonomics*, **3**, pp. 224–236.
- BURGE, P. S., 2004, Sick building Syndrome. *Occupational and Environmental Medicine*, **61**, pp. 185–190.
- CARLOPIO, J. R., 1996, Construct validity of a physical work environment satisfaction questionnaire. *Journal of Occupational Health Psychology*, **1**, pp. 330–344.
- CARLOPIO, J. R. and GARDNER, D., 1992, Direct and interactive effects of the physical work environment on attitudes. *Environment and Behavior*, **24**, pp. 579–601.
- COSJIN, E. P. E. M. and DEN HERTOOG, J. F., 1972, Beleven van het bureau-landschap (Experience of the Landscape Office). *Mens en Onderneming*, **26**, pp. 32–42.
- COTTON, P. and HART, P. M., 2003, Occupational wellbeing and performance: a review of organisational health research. *Australian Psychologist*, **38**, pp. 118–127.
- CROUCH, A. G. and NIMRAN, U., 1989, Office design and the behavior of senior managers. *Human Relations*, **42**, pp. 139–155.
- DAVIS, T. R., 1984, The influence of the physical environment in offices. *Academy of Management Review*, **9**, pp. 271–283.
- DE JONGE, J. and RUTTE, C., 1999, Een quasi-experimenteel veldonderzoek naar de psychologische effecten van een flexibel kantoorconcept (A quasi-experiment investigating the psychological effect of desk-sharing). *Gedrag en Organisatie*, **12**, pp. 427–444.
- DE LANGE, A. H., TARIS, T. W., KOMPIER, M. A. J., HOUTMAN, I. L. D. and BONGERS, P. M., 2002, Effects of stable and changing demand-control histories on worker health. *Scandinavian Journal of Work Environment and Health*, **28**, pp. 94–108.
- DE LOOZE, M. P., KUIJT-EVERS, L. F. M. and VAN DIEËN, J., 2004, Sitting comfort and discomfort and the relationships with objective measures. *Ergonomics*, **46**, pp. 985–997.
- DEMEROUTI, E., BAKKER, A. B., NACHREINER, F. and SCHAUFELI, W. B., 2001, The job demands–resources model of burnout. *Journal of Applied Psychology*, **86**, pp. 499–512.
- DESOR, J. A., 1972, Toward a psychological theory of crowding. *Journal of Personality and Social Psychology*, **21**, pp. 79–83.
- DUVALL-EARLY, K. and BENEDICT, J. O., 1992, The relationships between privacy and different components of job satisfaction. *Environment and Behavior*, **24**, pp. 670–679.
- EVANS, G. W. and JOHNSON, D., 2000, Stress and open-office noise. *Journal of Applied Psychology*, **85**, pp. 779–783.
- EVANS, G. W. and LEPORE, S. J., 1992, Crowding and human performance. *Journal of Applied Social Psychology*, **9**, pp. 163–173.
- FRIED, Y., 1990, Workspace characteristics, behavioral interferences and screening ability as joint predictors of employee reactions: an examination of the intensification approach. *Journal of Organizational Behavior*, **11**, pp. 267–280.
- FRIED, Y., SLOWIK, L. H., BEN-DAVID, H. A. and TIEGS, R. B., 2001, Exploring the relationship between workspace density and employee attitudinal reactions: an integrative model. *Journal of Occupational and Organizational Psychology*, **74**, pp. 359–372.
- GEEN, R. G. and GANGE, J. J., 1977, Drive theory of social facilitation: twelve years of theory and research. *Psychological Bulletin*, **84**, pp. 1267–1288.
- GIFFORD, R., 1997, *Environmental Psychology: Principles and Practice*, 2nd edition. (Boston, MA: Allyn and Bacon).
- HEDGE, A., 1984, Evidence of a relationship between office design and self-reports of ill health among office workers in the United Kingdom. *Journal of Architectural and Planning Research*, **1**, pp. 163–174.
- HEDGE, A., 2000, Where are we in understanding the effects of where we are? *Ergonomics*, **43**, pp. 1019–1029.



- HEDGE, A. and POWERS, J. R., 1995, Wrist postures while keyboarding – effects of a negative slope keyboard system and full-motion forearm supports. *Ergonomics*, **38**, pp. 508–517.
- HEERINK, E. M. G. and VERMEULEN, L. E., 2001, *Flex: de Werkplek van de 21e Eeuw: Onderzoek Naar de Invloed van Flexibele Werkplekken op de Effectiviteit van de Werkzaamheden-Ko Wierenga Stipendium* (Flexible workstations, the office of the new millennium: evaluation of the influence on work effectiveness) (Enschede: Saxion Hogeschool).
- HILL, E. J., MILLER, B. C., WEINER, S. P. and COLIHAN, J., 1998, Influences of the virtual office on aspects of work and work/life balance. *Personnel Psychology*, **51**, pp. 667–683.
- JAAKKOLA, J. J. K. and HEINONEN, O. P., 1995, Shared office space and the risk of common cold. *European Journal of Epidemiology*, **11**, pp. 213–216.
- KELLER, R. T., 1986, Predictors of the performance of project groups in R&D organizations. *Academy of Management Journal*, **29**, pp. 715–726.
- KOLSTAD, H. A., BRAUER, C., IVERSEN, M., SIGSGAARD, T. and MIKKELSEN, S., 2002, Do indoor molds in non-industrial environments threaten workers' health? A review of the epidemiologic evidence. *Epidemiologic Reviews*, **24**, pp. 203–217.
- KUPRITZ, V., 1998, Privacy in the work place: the impact of building design. *Journal of Environmental Psychology*, **18**, pp. 341–356.
- KURVERS, S., VAN DER LINDEN, K. and BOERSTRA, A. C., 2001, Individuele beïnvloeding: lager energiegebruik, gezonder, comfortabeler en productiever binnenmilieu, (Individual control over climate office conditions results in healthier, more comfortable and more productive indoor climate). *Facility Management Magazine*, December 2001, pp. 13–18.
- LIEVENSE, A. M., BIERMA-ZEINSTR, S. M. A., VERHAGEN, A. P., VERHAAR, J. A. N. and KOES, B. W., 2002, Prognostic factors of progress of hip osteoarthritis: a systematic review. *Arthritis & Rheumatism*, **47**, pp. 556–562.
- LUNDBERG, U. and LINDFORS, P., 2002, Psychophysiological reactions to telework in female and male white-collar workers. *Journal of Occupational Health Psychology*, **7**, pp. 354–364.
- MARANS, R. W. and YAN, X., 1989, Lighting quality and environmental satisfaction in open and enclosed offices. *The Journal of Architectural and Planning Research*, **6**, pp. 118–131.
- MENZIES, D. and BOURBEAU, J., 1997, Building-related illnesses. *New England Journal of Medicine*, **20**, pp. 1524–1531.
- O'BRIEN, G. E. and PEMBROKE, M., 1982, Crowding, density and the job satisfaction of clerical employees. *Australian Journal of Psychology*, **34**, pp. 151–164.
- OLDHAM, G. R., 1988, Effects of changes in workspace partitions and spatial density on employee reactions: a quasi-experiment. *Journal of Applied Psychology*, **73**, pp. 253–258.
- OLDHAM, G. R. and BRASS, D. J., 1979, Employee reactions to an open-plan office: a naturally occurring quasi-experiment. *Administrative Science Quarterly*, **24**, pp. 267–284.
- OLDHAM, G. R., CUMMINGS, A. and ZHOU, J. 1995, The spatial configuration of organizations: a review of the literature and some new research directions. *Research in Personnel and Human Resources Management*, **13**, pp. 1–37.
- OLDHAM, G. R. and FRIED, Y., 1987, Employee reactions to workspace characteristics. *Journal of Applied Psychology*, **72**, pp. 75–80.
- OLDHAM, G. R., KULIK, C. T. and STEPINA, L. P., 1991, Physical environments and employee reactions: effects of stimulus-screening skills and job complexity. *Academy of Management Journal*, **34**, pp. 929–938.
- OLDHAM, G. R. and ROTCHFORD, N. L., 1983, Relationship between office characteristics and employee reactions: a study of the physical environment. *Administrative Science Quarterly*, **28**, pp. 542–556.
- O'NEILL, M. J., 1994, Work space adjustability, storage and enclosure as predictors of employee reactions and performance, *Environment and Behavior*, **26**, pp. 504–526.
- OLSON, M. H., 1989, Work at home for computer professionals: current attitudes and future prospects. *ACM Transactions on Office Information Systems*, **7**, pp. 317–338.
- PULLEN, W. and BRADLEY, S., 2004, Modernising government workplaces: towards evidence, as well as experience, *Facilities*, **22**, pp. 70–73.
- RISHI, P., SINHA, S. P. and DUBEY, R., 2000, A correlational study of workspace characteristics and work satisfaction among Indian bank employees. *Psychologia*, **43**, pp. 155–164.
- SLAVIN, R. E., 1995, Best evidence synthesis: an intelligent alternative to meta-analysis. *Journal of Clinical Epidemiology*, **48**, pp. 9–18.
- SLUITER, J. K., DE CROON, E. M., MEIJMAN, T. F. and FRINGS-DRESEN, M. H. W., 2003, Need for recovery from work related fatigue and its role in the development and prediction of subjective health complaints. *Occupational and Environmental Medicine*, **60**, pp. 62i–70i.



- STANDEN, P., DANIELS, K. and LAMOND, D., 1999, The home as a workplace: work-family interaction and psychological well-being in telework. *Journal of Occupational Health Psychology*, **4**, pp. 368–381.
- STOKOLS, D., 1972, On the distinction between density and crowding: some implications for future research. *Psychological Review*, **79**, pp. 275–277.
- SUNDSTROM, E., BURT, R. E. and KAMP, D., 1980, Privacy at work: architectural correlates of job satisfaction and job performance. *Academy of Management Journal*, **23**, pp. 101–117.
- SUNDSTROM, E., KRING HERBERT, R. and BROWN, D. W., 1982a, Privacy and communication in an open-plan office: a case study. *Environment and Behavior*, **14**, pp. 279–392.
- SUNDSTROM, E., TOWN, J. P., BROWN, D. W., FORMAN, A. and MCGEE, G., 1982b, Physical enclosure, type of job and privacy in the office. *Environment and Behavior*, **14**, pp. 543–559.
- SUTTON, R. and RAFAELI, A., 1987, Characteristics of work stations as potential stressors. *Academy of Management Journal*, **30**, pp. 260–276.
- SZILAGY, A. D. and HOLLAND, W. E., 1980, Changes in social density: relationships with functional interaction and perception of job characteristics, role stress and work satisfaction. *Journal of Applied Psychology*, **65**, pp. 28–33.
- VAN DEN BRINK, A., 2000, *Flexido, De Effecten in Kaart*. (Flexido, Evaluation of desk-sharing at ABN/AMRO) (Amsterdam: ABN AMRO, DOI&H Concern Huisvesting en Vastgoed, Taskforce flexibel Werken).
- VAN DIJK, F. J. H., VAN DORMOLEN, M., KOMPIER, M. A. J. and MEIJMAN, T. F., 1990, Herwaarderend model belasting-belastbaarheid (Reappraisal of the model of workload and capacity). *Tijdschrift Sociale Gezondheidszorg*, **68**, pp. 3–10.
- VAN WIJK, H., 1999, *What's in an Office: Een Onderzoek Naar Het Verschil Tussen Een Cellen – En Een Combikantoor Wat Betreft Privacy, Concentratie En Communicatie* (What's in an office: a study on the differences between a traditional enclosed office and a cocon office as regards privacy, concentration and communication) (Eindhoven: University of Eindhoven, Faculty of Technology Management).
- VASMATZIDIS, I., SCHLEGEL, R. E. and HANCOCK, P. A., 2002, An investigation of heat stress effects on time-sharing performance. *Ergonomics*, **45**, pp. 218–239.
- VOS, P. G. J. C. and DEWULF, P. M. R., 1998, *Werkt Het Beter in Het Dynamisch Kantoor Haarlem?* (Does it work better in the Haarlem dynamic office?) (Delft: Bouwmanagement & Vastgoedbeheer, University of Delft, Department of Architecture).
- VOS, P. G. J. C., DIJCKS, A. and VAN MEEL, J. J., 1999, *The Office, the Whole Office and Nothing But the Office: A Framework of Workplace Concepts* (Delft: Bouwmanagement & Vastgoedbeheer, University of Delft, Department of Architecture).
- VOS, P. G. J. C. and VAN DER VOORDT, D. J. M., 2002, Tomorrow's offices through today's eyes, effects of office innovation in the working environment. *Journal of Corporate Real Estate*, **4**, pp. 48–65.
- WINEMAN, J. D. 1982, Office design and evaluation: an overview, *Environment and Behavior*, **14**, pp. 271–298.
- WOLLMANN, N., KELLY, B. M. and BORDENS, K. S., 1994, Environmental and intrapersonal predictors to potential territorial intrusions in the workplace. *Environment and Behavior*, **26**, pp. 179–194.
- ZAHN, G. L., 1992, Face-to-face communication in an office setting: The effects of position, proximity and exposure. *Communication Research*, **18**, pp. 737–754.
- ZALESNY, M. D. and FARACE, R. V., 1987, Traditional versus open offices: a comparison of sociotechnical, social relations and symbolic meaning perspectives. *Academy of Management Journal*, **30**, pp. 240–259.
- ZHOU, J., OLDFHAM, G. R. and CUMMINGS, A., 1998, Employee reactions to the physical work environment: the role of childhood residential attributes. *Journal of Applied Social Psychology*, **28**, pp. 2213–2238.