Data Description of the Mechanical Shaker Experiments: Amsterdam Study into the Properties of Wearable Accelerometers (ASPWA)

Annelinde Lettink[1,2,3], Wessel N. van Wieringen[2,4,5], Teatske M. Altenburg[1,2,3], Mai J.M Chinapaw[1,2,3], and Vincent T. van Hees[6]

[1]Amsterdam UMC location Vrije Universiteit Amsterdam, Public and Occupational Health, De Boelelaan 1117, Amsterdam, The Netherlands
[2]Amsterdam Public Health, Methodology, Amsterdam, The Netherlands
[3]Amsterdam Public Health, Health Behaviors & Chronic Diseases, Amsterdam, The Netherlands
[4]Amsterdam UMC location Vrije Universiteit Amsterdam, Epidemiology and Data Science, De Boelelaan 1117, Amsterdam, The Netherlands
[5]Department of Mathematics, Vrije Universiteit Amsterdam, De Boelelaan 1111, 1081 HV, Amsterdam, The Netherlands
[6]Accelting, Almere, The Netherlands

August 16, 2023

This archive holds the data we collected in the Amsterdam Study into the Properties of Wearable Accelerometers (ASPWA) as used in physical behavior and sleep research.

Contents

1 Experimental Protocol

The experiments took place in November 2020 at the Amsterdam University Medical Centers, Vrije Universiteit Amsterdam, The Netherlands. A detailed outline of the timing for all experiments can be found in the labels file: data_description_new.csv. In summary, the experiments as presented in Table 1 involved the following parts:

Experiment name	**Short description**	**Included in article**
ms_lrcr	Shaker machine - low sampling rate	✓
ms_hrcr	Shaker machine - high sampling rate	✓
ms_mrcr	Shaker machine - mixed sampling rate	✓
ms_lrmr	Shaker machine - low sampling rate + mixed dynamic range	✓
ms_hrmr	Shaker machine - high sampling rate + mixed dynamic range	✓
ms_bag	Shaker machine - all in bag	
timer_check	In the box for all day, turned at specific times	✓
box	In a box, held still repeatedly in various orientations for at least 30 seconds	✓
door	Door experiment	

Table 1: Experiment names with short description.

1.1 Accelerometers attached to the shaker machine

Accelerometers were attached with double-sided tape to a mechanical shaker machine (SM25 B; Edmund Bühler, Deutschland model as previously described in [1] see Figure 1). The accelerometers were shaken along a single axis in the horizontal plane at 19 different shaker frequency conditions for two minutes each (see this video for a visual explanation). The mechanical shaker machine is controlled with an analogue wheel at: 30, 40, 50, 62, 75, 87, 100, 112, 125, 137, 150, 162, 175, 187, 200, 212, 225, 237, and 250 rotations per minute (rpm). This was repeated with various accelerometer configurations, including: sampling rate and dynamic range.

(a) (b)

Figure 1: Attachment of the accelerometers to the mechanical shaker machine during the *ms_lrcr*, *ms_hrcr* and *ms_mrcr* (a) and *ms_lrmr* and *ms_hrmr* (b) experiments.

1.2 Accelerometers in bag attached to the shaker machine

Accelerometers were placed in a bag with random orientations which was then tightly taped to the mechanical shaker machine (see Figure 2). The accelerometers were then shaken at the 19 different shaker frequency conditions.

Figure 2: Attachment of the accelerometers in the bag to the mechanical shaker machine during the *ms_bag* experiment.

1.3 Accelerometers in box

Accelerometers were placed in a cardbord box while leaving it there for half a day while only turning the box at the beginning and the end to help study the timekeeping property of the accelerometers during the *timer_check* experiment. Accelerometers were placed tightly in a cardboard box complemented with foam to fill up empty spaces. The box was held repeatedly still for at least 30 seconds in various random orientations to help investigate device calibration relative to gravity (see Figure 3) during the *box* experiment.

1.4 Accelerometers attached to door

Attaching a subset of the accelerometers with double-sided tape to a door (see Figure 4). The door was opened and closed manually at low frequencies. We did this to investigate whether such a simple low-cost experiment can be used as a more feasible alternative to a mechanical shaker experiment to get a quick impression of the comparability of accelerometers in the epidemiological field.

Figure 3: Accelerometers placed in a cardboard box during the *box* experiment.

Figure 4: Attachment of a subset the accelerometers during the *door* experiment.

2 Accelerometer devices

We used accelerometers from the following brands and models. For each brand, the number of devices used, the software version for initializing the device, and firmware version are indicated below in Table 2.

2.1 Accelerometer device configurations

An overview of the accelerometer devices included and their configurations in each experiment is presented below in Table 3. In the experiments performed at high sampling rate (*hr*), we set the sampling rate at 100 Hertz (Hz) or as close as possible. In the experiments performed at low sampling rate (*lr*), we set the sampling rate at 25 Hz or as close as possible. In the experiments performed with mixed sampling rate (*mr*), we set the sampling rate ranging between 10 and 1600 Hz, depending on the available configuration options per brand. The dynamic range was either constant for all devices (*cr*; 8 *g* except for: activPAL 2 *g*, and ActiGraph with CLE in serial number 6 *g*), or with different dynamic ranges for different devices of the same brand, which we will refer to as mixed dynamic range (*mr*; 2, 4, 8, or 16 *g*)

Brand, manufacturer	**Model/type**	**Number of devices used**	**Firmware version**	**Software version for initalization**
ActiGraph, ActiGraph LLS, USA	GT3X+ (CLE in serial number)	9	2.5.0	ActiLife v6.13.3
	wGT3X+ (CLE in serial number)	1		
	wGT3X-BT (MOS in serial number)	10	1.9.2	
activPAL, PAL Technologies Ltd., UK	micro 3	15	3.4.0	PALconnect v.8.11.6.94
Condor, Condor Instruments Ltda., Brazil	Acttrust2	10	1.2	ActStudio v1.0.10
Axivity, Axivity Ltd., UK	AX3	15	44	OmGui v44
GENEActiv, ActivInsights Ltd., UK	Original	8	Ver4.08a date14Jul14	GENEActivPCSoftware 3.3 Build 2019-06-21
	Sleep	2		
MOX, Maastricht Instruments B.V., The Netherlands	Logger	4	unknown	unknown
Shimmer, Shimmer Research Ltd., Ireland	Shimmer3 IMU	1	FW Shimmer2 Workbench: TI CCS v7.2.0.00013 Compiler: TI v4.4.8	ConsensysPRO v1.0.0
Fitbit, Fitbit LLC, USA	unknown	2	unknown	unknown

Table 2: Brand, model, number, firmware, and software for initialization of the devices.

Experiment name	**Device configurations**		**ID on shaker machine**	**Brand model**	**Number of resulting signals**
	Sampling rate (Hz)	Dynamic range (g)			
ms_hrmr	100	2	4	Axivity AX3	4
		4	4		4
		8	4		3[a]
		16	3		3
ms_lrmr	25	2	4	Axivity AX3	4
		4	3		3
		8	3		3
		16	5		5[b]
ms_hrcr	100	6	9/1	ActiGraph GT3X+/wGT3X+	9/1[c]
		8	10	ActiGraph wGT3X-BT	10[c]
			10	GENEActiv Original and Sleep	10
			15	Axivity AX3	15
			4	MOX	4[a]
	20	2	15	activPAL micro3	13[b,d]
	NA	NA	10	Acttrust2	10
			1	Shimmer3 IMU	1
			2	Fitbit	2
ms_lrcr	25	8	10	GENEActiv Original and Sleep	10
			15	Axivity AX3	15[b]
			4	MOX	4
			10	ActiGraph wGT3X-BT	10[b]
		6	9/1	ActiGraph GT3X+/wGT3X+	9/1[b]
	20	2	15	activPAL micro3	13[b, d, e]
	NA	NA	10	Acttrust2	10[b]
			1	Shimmer3 IMU	1[b]
			2	Fitbit	2
ms_mrcr	20	2	15	activPAL micro3	13[d]
	50	6	1	ActiGraph wGT3X+	1
	30/40/50/60/ 70/80/90/100		1/1/2/1/ 1/1/1/1	ActiGraph GT3X+	1/1/2/1/ 1/1/1/1
		8	1/1/3/1/ 1/1/1/1	ActiGraph wGT3X-BT	1/1/3/1/ 1/1/1/1

Table 3 continued from previous page

Experiment name	Device configurations		ID on shaker machine	Brand model	Number of resulting signals
	Sampling rate (Hz)	Dynamic range (g)			
	10/20/30/40/50/ 60/66.7/75/85.5/100 12/25/100/200/ 400/800/1600 25/100		1/1/1/1/1/ 1/1/1/1/1	GENEActiv Original and Sleep	1/1/1/1/1/ 1/1/1/1/1
			3/2/2/2/ 1/2/1	Axivity AX3	3/2/2/2/ 1/2/1
			2/2	MOX	2/2
	NA	NA	1	Shimmer3 IMU	1
			10	Acttrust2	10
			2	Fitbit	2
ms_bag	100	6	9/1	ActiGraph GT3X+/wGT3X+	9/1
		8	10	ActiGraph wGT3X-BT	10
			10	GENEActiv Original and Sleep	10
			15	Axivity AX3	15
			4	MOX	4
	20	2	14	activPAL micro3	14
	NA	NA	10	Acttrust2	10
			1	Shimmer3 IMU	1
timer_check	100	6	9/1	ActiGraph GT3X+/wGT3X+	9/1
		8	10	ActiGraph wGT3X-BT	10
			15	Axivity AX3	15
			10	GENEActiv Original and Sleep	10
			4	MOX	4
	20	2	14	activPAL micro3	13[d]
	NA	NA	10	Acttrust2	10
			1	Shimmer3 IMU	1
			2	Fitbit	2
box	20	2	14	activPAL micro3	13[d]
	50	8	1	ActiGraph wGT3X+	1
			14	Axivity AX3	14
			10	GENEActiv Original and Sleep	10
			4	MOX	4

Table 3 continued from previous page

Experiment name	Device configurations		ID on shaker machine	Brand model	Number of resulting signals
	Sampling rate (Hz)	Dynamic range (g)			
	30/40/50/60/ 70/80/90/100		1/1/3/1/ 1/1/1/1	ActiGraph wGT3X-BT	1/1/3/1/ 1/1/1/1
		6	1/2/2/1/ 1/1/1/1	ActiGraph GT3X+	1/2/2/1/ 1/1/1/1
	NA	NA	10	Acttrust2	10
			1	Shimmer3 IMU	1
			2	Fitbit	2
door	100	6	4	ActiGraph GT3X+	4
		8	4	ActiGraph wGT3X-BT	4
			10	Axivity AX3	10
			4	GENEActiv Original and Sleep	4
			4	MOX	4
	20	2	6	activPAL micro3	6
	NA	NA	1	Shimmer3 IMU	1

Note - List of known deviations from the protocol

[a] Incorrect initialization of the device, as a result no data was recorded (*ms_hrmr*: Ax_215; *ms_hrcr*: Ax_287; *ms_lrcr*: AG_CLE_056), or recording stopped 31 minutes earlier than the end of the experiment (*ms_hrcr*: MOX_365, MOX_366, MOX_475, and , MOX_828)

[b] Configured sampling rate did not correspond to the intended experimental sampling rate (*ms_lrmr*: Ax_215 was set to 100 Hz; *ms_hrcr*: activPAL devices were set to 20 Hz and ActiGraph and Acttrust devices to 30 Hz, because these were the lowest sampling rate configurations available for these brands)

[c] IDLE sleep mode was accidentally turned on in 3/1/5 GT3X+/wGT3X+/wGT3X-BT ActiGraph devices (*ms_hrcr*: AG_CLE_039, AG_CLE_077, AG_CLE_091, AG_CLE_132, AG_MOS_028, AG_MOS_192, AG_MOS_352, and AG_MOS_008)

[d] The device was defect (*ms_hrcr/ms_lrcr/ms_mrcr*: aP_493) or its battery capacity was low (*ms_hrcr/ms_lrcr/ms_mrcr*: aP_258; *timer_check*: aP_488), as a result it did not record any data during the experiments

[e] Acceleration signal showed large variations indicative of potential device defects (*ms_lrcr*: aP_490 and aP_245)

Table 3: Accelerometer device configurations and the resulting number of data files per experiment.

3 Folder structure

Data are stored in their raw unstructured format (unstructured_raw_data.zip) as well as in structured format (structured_raw_data.zip). Each subfolder reflects the name of the accelerometer brand and the name of the experiment (as previously described in Table 1).

3.1 Unstructured data

The exact configuration per accelerometer device is included inside the unstructured accelerometer files.

3.2 Structured data

The scripts required to structure the data included in the article can be found in our GitHub repository: mechanicalshakerexperiments.

References

[1] V. Van Hees, S. Slootmaker, G. De Groot, W. Van Mechelen, and R. Van Lummel, "Reproducibility of a triaxial seismic accelerometer," *Medicine and Science in Sports & Exercise*, vol. 41, no. 2, p. 810, 2009.