An Evaluation of HOLD: A Remote Haptic Handshaking System for Telerobots - Results

I. HANDSHAKE REPRESENTATION

TABLE I
HANDSHAKE REP. - REPEATED MEASURES ANOVAS

Analysis	df	Error df	F	p
Rocker Profile	2.204	37.467	8.500	< .001
Squeeze Profiles	4.000	68.000	49.268	< .001
Vibration Profiles	6.000	102.000	3.766	0.002
Modality	3.000	51.000	24.520	< .001

TABLE II
HANDSHAKE REP. - BONFERRONI TEST POST HOC COMPARISONS

Comparison		M Diff.	SE	t	p$_{bonf}$
Slow Short	Slow Long	0.056	0.127	0.437	1.000
	Fast Short	0.000	0.081	0.000	1.000
	Fast Long	0.000	0.114	0.000	1.000
	Control	0.556	0.121	4.610	0.002
Slow Long	Fast Short	−0.056	0.098	−0.566	1.000
	Fast Long	−0.056	0.056	−1.000	1.000
	Control	0.500	0.167	3.000	0.081
Fast Short	Fast Long	0.000	0.081	0.000	1.000
	Control	0.556	0.145	3.828	0.013
Fast Long	Control	0.556	0.145	3.828	0.013
Slow Static	Slow Cyc.	0.000	0.081	0.000	1.000
	Fast Static	−0.056	0.056	−1.000	1.000
	Fast Cyc.	0.056	0.056	1.000	1.000
	Control	0.833	0.090	9.220	< .001
Slow Cyc.	Fast Static	−0.056	0.056	−1.000	1.000
	Fast Cyc.	0.056	0.056	1.000	1.000
	Control	0.833	0.090	9.220	< .001
Fast Static	Fast Cyc.	0.111	0.076	1.458	1.000
	Control	0.889	0.076	11.662	< .001
Fast Cyc.	Control	0.778	0.101	7.714	< .001
Slow Static	Slow Seq.	−0.056	0.127	−0.437	1.000
	Slow Oscil.	−0.056	0.151	−0.369	1.000
	Fast Static	−0.278	0.135	−2.051	1.000
	Fast Seq.	0.000	0.114	0.000	1.000
	Fast Oscil.	−0.056	0.151	−0.369	1.000
	Control	0.333	0.140	2.380	0.614
Slow Seq.	Slow Oscil.	0.000	0.114	0.000	1.000
	Fast Static	−0.222	0.152	−1.458	1.000
	Fast Seq.	0.056	0.098	0.566	1.000
	Fast Oscil.	0.000	0.114	0.000	1.000
	Control	0.389	0.118	3.289	0.091
Slow Oscil.	Fast Static	−0.222	0.129	−1.719	1.000
	Fast Seq.	0.056	0.151	0.369	1.000
	Fast Oscil.	0.000	0.140	0.000	1.000
	Control	0.389	0.143	2.715	0.309
Fast Static	Fast Seq.	0.278	0.158	1.761	1.000
	Fast Oscil.	0.222	0.129	1.719	1.000
	Control	0.611	0.118	5.169	0.002
Fast Seq.	Fast Oscil.	−0.056	0.127	−0.437	1.000
	Control	0.333	0.114	2.915	0.202
Fast Oscil.	Control	0.389	0.118	3.289	0.091
Rocker	Squeeze	−5.517	1.181	−4.669	0.001
	Vibration	1.106	1.556	0.711	1.000
	Control	11.628	1.506	7.721	< .001
Squeeze	Vibration	6.622	1.305	5.076	< .001
	Control	17.144	1.148	14.934	< .001
Vibration	Control	10.522	1.405	7.489	< .001

II. EMOTIONAL RESPONSE TO STIMULI

TABLE III
PLEASURE - REPEATED MEASURES ANOVAS

Analysis	df	Error df	F	p
Rocker Profiles	1.787	30.373	3.574	0.045
Squeeze Profiles	2.295	39.012	10.578	< .001
Vibration Profiles	2.901	49.324	4.098	0.012
Modality	1.919	32.626	9.029	< .001

TABLE IV
PLEASURE - BONFERRONI TEST POST HOC COMPARISONS

Comparison		M Diff.	SE	t	p$_{bonf}$
Slow Short	Slow Long	−0.151	0.390	−0.386	1.000
	Fast Short	0.250	0.470	0.531	1.000
	Fast Long	0.305	0.417	0.731	1.000
	Control	1.451	0.511	2.837	0.114
Slow Long	Fast Short	0.401	0.217	1.848	0.821
	Fast Long	0.456	0.176	2.588	0.192
	Control	1.602	0.669	2.394	0.285
Fast Short	Fast Long	0.055	0.246	0.223	1.000
	Control	1.201	0.621	1.933	0.700
Fast Long	Control	1.146	0.671	1.708	1.000
Slow Static	Slow Cyc.	−0.038	0.277	−0.138	1.000
	Fast Static	−0.102	0.459	−0.222	1.000
	Fast Cyc.	−0.009	0.200	−0.044	1.000
	Control	2.324	0.561	4.144	0.007
Slow Cyc.	Fast Static	−0.063	0.296	−0.214	1.000
	Fast Cyc.	0.029	0.313	0.094	1.000
	Control	2.363	0.566	4.177	0.006
Fast Static	Fast Cyc.	0.093	0.515	0.180	1.000
	Control	2.426	0.614	3.949	0.010
Fast Cyc.	Control	2.333	0.567	4.114	0.007
Slow Static	Slow Seq.	−0.082	0.224	−0.367	1.000
	Slow Oscil.	−0.070	0.305	−0.230	1.000
	Fast Static	−0.006	0.340	−0.016	1.000
	Fast Seq.	0.431	0.284	1.517	1.000
	Fast Oscil.	−0.004	0.423	−0.010	1.000
	Control	1.652	0.665	2.484	0.498
Slow Seq.	Slow Oscil.	0.012	0.285	0.043	1.000
	Fast Static	0.077	0.300	0.256	1.000
	Fast Seq.	0.513	0.278	1.850	1.000
	Fast Oscil.	0.078	0.329	0.237	1.000
	Control	1.734	0.593	2.927	0.198
Slow Oscil.	Fast Static	0.064	0.444	0.145	1.000
	Fast Seq.	0.501	0.385	1.300	1.000
	Fast Oscil.	0.066	0.471	0.139	1.000
	Control	1.722	0.670	2.569	0.418
Fast Static	Fast Seq.	0.437	0.303	1.439	1.000
	Fast Oscil.	0.001	0.298	0.004	1.000
	Control	1.658	0.624	2.657	0.348
Fast Seq.	Fast Oscil.	−0.436	0.356	−1.223	1.000
	Control	1.221	0.619	1.974	1.000
Fast Oscil.	Control	1.657	0.578	2.864	0.226
Rocker	Squeeze	−1.012	0.246	−4.116	0.004
	Vibration	−0.257	0.356	−0.723	1.000
	Control	1.351	0.587	2.303	0.205
Squeeze	Vibration	0.755	0.363	2.082	0.317
	Control	2.363	0.534	4.426	0.002
Vibration	Control	1.608	0.586	2.745	0.083

TABLE V
AROUSAL - REPEATED MEASURES ANOVAS

Analysis	df	Error df	F	p
Rocker Profiles	1.963	29.446	13.620	< .001
Vibration Profiles	6.000	90.000	5.309	< .001
Modality	1.870	28.056	13.430	< .001

TABLE VI
AROUSAL - BONFERRONI TEST POST HOC COMPARISONS

Comparison		M Diff.	SE	t	p_{bonf}
Slow Short	Slow Long	0.079	0.225	0.353	1.000
	Fast Short	−0.358	0.147	−2.442	0.275
	Fast Long	−0.440	0.151	−2.909	0.108
	Control	1.259	0.332	3.793	0.018
Slow Long	Fast Short	−0.438	0.216	−2.028	0.607
	Fast Long	−0.519	0.201	−2.585	0.207
	Control	1.179	0.335	3.518	0.031
Fast Short	Fast Long	−0.082	0.111	−0.736	1.000
	Control	1.617	0.390	4.148	0.009
Fast Long	Control	1.699	0.335	5.077	0.001
Slow Static	Slow Seq.	−0.289	0.293	−0.986	1.000
	Slow Oscil.	0.161	0.293	0.548	1.000
	Fast Static	−0.552	0.272	−2.028	1.000
	Fast Seq.	−0.347	0.303	−1.147	1.000
	Fast Oscil.	−0.265	0.224	−1.183	1.000
	Control	1.112	0.353	3.148	0.139
Slow Seq.	Slow Oscil.	0.449	0.245	1.835	1.000
	Fast Static	−0.263	0.381	−0.690	1.000
	Fast Seq.	−0.059	0.399	−0.147	1.000
	Fast Oscil.	0.024	0.264	0.090	1.000
	Control	1.401	0.369	3.793	0.037
Slow Oscil.	Fast Static	−0.712	0.296	−2.408	0.616
	Fast Seq.	−0.508	0.421	−1.208	1.000
	Fast Oscil.	−0.426	0.274	−1.554	1.000
	Control	0.951	0.358	2.658	0.376
Fast Static	Fast Seq.	0.204	0.415	0.493	1.000
	Fast Oscil.	0.287	0.344	0.835	1.000
	Control	1.664	0.499	3.333	0.095
Fast Seq.	Fast Oscil.	0.083	0.265	0.311	1.000
	Control	1.459	0.376	3.878	0.031
Fast Oscil.	Control	1.377	0.346	3.978	0.025
Rocker	Squeeze	−0.006	0.117	−0.053	1.000
	Vibration	0.111	0.183	0.604	1.000
	Control	1.438	0.331	4.343	0.003
Squeeze	Vibration	0.117	0.259	0.452	1.000
	Control	1.444	0.333	4.342	0.003
Vibration	Control	1.327	0.328	4.040	0.006

TABLE VII
AROUSAL - FRIEDMAN TESTS

Analysis	$X^2{}_F$	df	Kendall's W	p
Squeeze Profiles	28.746	4	0.449	< .001

TABLE VIII
AROUSAL - CONOVER'S TEST POST HOC COMPARISONS

Comparison		W_i	W_j	T-Stat	p_{bonf}
Slow Static	Slow Cyc.	42.500	64.000	3.305	0.016
	Fast Static	42.500	52.500	1.537	1.000
	Fast Cyc.	42.500	70.000	4.227	< .001
	Control	42.500	26.000	2.536	0.137
Slow Cyc.	Fast Static	64.000	52.500	1.768	0.819
	Fast Cyc.	64.000	70.000	0.922	1.000
	Control	64.000	26.000	5.841	< .001
Fast Static	Fast Cyc.	52.500	70.000	2.690	0.091
	Control	52.500	26.000	4.073	0.001
Fast Cyc.	Control	70.000	26.000	6.763	< .001

TABLE IX
DOMINANCE - FRIEDMAN TESTS

Analysis	$X^2{}_F$	df	Kendall's W	p
Rocker Profiles	5.313	4	0.078	0.257
Squeeze Profiles	7.552	4	0.118	0.109
Vibration Profiles	8.703	6	0.091	0.191
Modality	9.304	3	0.194	0.026

TABLE X
DOMINANCE - CONOVER'S TEST POST HOC COMPARISONS

Comparison		W_i	W_j	T-Stat	p_{bonf}
Rocker	Squeeze	35.000	32.000	0.477	1.000
	Vibration	35.000	42.000	1.113	1.000
	Control	35.000	51.000	2.544	0.087
Squeeze	Vibration	32.000	42.000	1.590	0.713
	Control	32.000	51.000	3.021	0.025
Vibration	Control	42.000	51.000	1.431	0.956

III. PRESENCE

TABLE XI
TELEPRESENCE - FRIEDMAN TESTS

Analysis	X^2_F	df	Kendall's W	p
Rocker Profiles	31.656	4	0.440	< .001
Squeeze Profiles	39.365	4	0.547	< .001
Vibration Profiles	46.827	6	0.434	< .001
Modality	38.067	3	0.705	< .001

TABLE XII
TELEPRESENCE - SIGNIFICANT CONOVER'S POST HOC COMPARISONS

Comparison		W_i	W_j	T-Stat	p_{bonf}
Slow Short	Slow Long	58.500	62.000	0.486	1.000
	Fast Short	58.500	59.500	0.139	1.000
	Fast Long	58.500	68.500	1.390	1.000
	Control	58.500	21.500	5.143	< .001
Slow Long	Fast Short	62.000	59.500	0.347	1.000
	Fast Long	62.000	68.500	0.903	1.000
	Control	62.000	21.500	5.629	< .001
Fast Short	Fast Long	59.500	68.500	1.251	1.000
	Control	59.500	21.500	5.282	< .001
Fast Long	Control	68.500	21.500	6.533	< .001
Slow Static	Slow Cyc.	58.500	61.500	0.470	1.000
	Fast Static	58.500	68.500	1.566	1.000
	Fast Cyc.	58.500	63.500	0.783	1.000
	Control	58.500	18.000	6.341	< .001
Slow Cyc.	Fast Static	61.500	68.500	1.096	1.000
	Fast Cyc.	61.500	63.500	0.313	1.000
	Control	61.500	18.000	6.811	< .001
Fast Static	Fast Cyc.	68.500	63.500	0.783	1.000
	Control	68.500	18.000	7.907	< .001
Fast Cyc.	Control	63.500	18.000	7.124	< .001
Slow Static	Slow Seq.	64.500	81.000	1.701	1.000
	Slow Oscil.	64.500	70.000	0.567	1.000
	Fast Static	64.500	98.500	3.506	0.014
	Fast Seq.	64.500	79.500	1.547	1.000
	Fast Oscil.	64.500	88.500	2.475	0.315
	Control	64.500	22.000	4.382	< .001
Slow Seq.	Slow Oscil.	81.000	70.000	1.134	1.000
	Fast Static	81.000	98.500	1.804	1.000
	Fast Seq.	81.000	79.500	0.155	1.000
	Fast Oscil.	81.000	88.500	0.773	1.000
	Control	81.000	22.000	6.083	< .001
Slow Oscil.	Fast Static	70.000	98.500	2.939	0.086
	Fast Seq.	70.000	79.500	0.980	1.000
	Fast Oscil.	70.000	88.500	1.908	1.000
	Control	70.000	22.000	4.949	< .001
Fast Static	Fast Seq.	98.500	79.500	1.959	1.000
	Fast Oscil.	98.500	88.500	1.031	1.000
	Control	98.500	22.000	7.888	< .001
Fast Seq.	Fast Oscil.	79.500	88.500	0.928	1.000
	Control	79.500	22.000	5.929	< .001
Fast Oscil.	Control	88.500	22.000	6.857	< .001
Rocker	Squeeze	50.000	66.000	3.696	0.003
	Vibration	50.000	45.000	1.155	1.000
	Control	50.000	19.000	7.160	< .001
Squeeze	Vibration	66.000	45.000	4.850	< .001
	Control	66.000	19.000	10.856	< .001
Vibration	Control	45.000	19.000	6.005	< .001

TABLE XIII
SOCIAL PRESENCE - FRIEDMAN TESTS

Analysis	X^2_F	df	Kendall's W	p
Rocker Profiles	21.702	4	0.301	< .001
Squeeze Profiles	39.457	4	0.548	< .001
Vibration Profiles	30.425	6	0.282	< .001
Modality	34.074	3	0.631	< .001

TABLE XIV
SOCIAL PRESENCE - CONOVER'S POST HOC COMPARISONS

Comparison		W_i	W_j	T-Stat	p_{bonf}
Slow Short	Slow Long	59.000	60.000	0.137	1.000
	Fast Short	59.000	61.000	0.274	1.000
	Fast Long	59.000	61.000	0.274	1.000
	Control	59.000	29.000	4.104	0.001
Slow Long	Fast Short	60.000	61.000	0.137	1.000
	Fast Long	60.000	61.000	0.137	1.000
	Control	60.000	29.000	4.241	< .001
Fast Short	Fast Long	61.000	61.000	0.000	1.000
	Control	61.000	29.000	4.377	< .001
Fast Long	Control	61.000	29.000	4.377	< .001
Slow Static	Slow Cyc.	61.000	59.500	0.233	1.000
	Fast Static	61.000	71.000	1.554	1.000
	Fast Cyc.	61.000	60.500	0.078	1.000
	Control	61.000	18.000	6.683	< .001
Slow Cyc.	Fast Static	59.500	71.000	1.787	0.783
	Fast Cyc.	59.500	60.500	0.155	1.000
	Control	59.500	18.000	6.450	< .001
Fast Static	Fast Cyc.	71.000	60.500	1.632	1.000
	Control	71.000	18.000	8.237	< .001
Fast Cyc.	Control	60.500	18.000	6.605	< .001
Slow Static	Slow Seq.	76.000	80.000	0.393	1.000
	Slow Oscil.	76.000	73.500	0.246	1.000
	Fast Static	76.000	85.500	0.933	1.000
	Fast Seq.	76.000	72.500	0.344	1.000
	Fast Oscil.	76.000	85.000	0.884	1.000
	Control	76.000	31.500	4.370	< .001
Slow Seq.	Slow Oscil.	80.000	73.500	0.638	1.000
	Fast Static	80.000	85.500	0.540	1.000
	Fast Seq.	80.000	72.500	0.737	1.000
	Fast Oscil.	80.000	85.000	0.491	1.000
	Control	80.000	31.500	4.763	< .001
Slow Oscil.	Fast Static	73.500	85.500	1.178	1.000
	Fast Seq.	73.500	72.500	0.098	1.000
	Fast Oscil.	73.500	85.000	1.129	1.000
	Control	73.500	31.500	4.125	0.002
Fast Static	Fast Seq.	85.500	72.500	1.277	1.000
	Fast Oscil.	85.500	85.000	0.049	1.000
	Control	85.500	31.500	5.303	< .001
Fast Seq.	Fast Oscil.	72.500	85.000	1.228	1.000
	Control	72.500	31.500	4.026	0.002
Fast Oscil.	Control	85.000	31.500	5.254	< .001
Rocker	Squeeze	47.500	66.000	3.864	0.002
	Vibration	47.500	45.000	0.522	1.000
	Control	47.500	21.500	5.431	< .001
Squeeze	Vibration	66.000	45.000	4.386	< .001
	Control	66.000	21.500	9.295	< .001
Vibration	Control	45.000	21.500	4.908	< .001

IV. POST STUDY

TABLE XV
FAVORITE PROFILE - POST-STUDY RANKING

Profile	*M*	Std. Dev.	Rank
Control	-0.67	0.82	15
Slow Short	2.33	1.75	9
Slow Long	1.50	2.51	10
Fast Short	1.50	2.07	10
Fast Long	0.50	1.73	14
Slow Static	3.50	1.51	1
Slow Cycling	3.50	1.68	1
Fast Static	2.91	1.45	5
Fast Cycling	2.60	1.58	7
Slow Static	2.50	2.51	8
Slow Sequential	2.80	1.48	6
Slow Oscillatory	1.50	2.08	10
Fast Static	3.33	2.08	3
Fast Sequential	1.20	2.05	13
Fast Oscillatory	3.00	1.63	4

TABLE XVI
FAVORITE MODALITY - POST-STUDY RANKING

Modality	*M*	Std. Dev.	Rank
Control	1.33	0.49	4
Rocker	2.33	0.84	3
Squeeze	3.61	0.61	1
Vibration	2.72	1.07	2