

RESEARCH ARTICLE



R E : 26 S : b 2005 / A E : 16 JY 2006 / P b : 10 A 2006  
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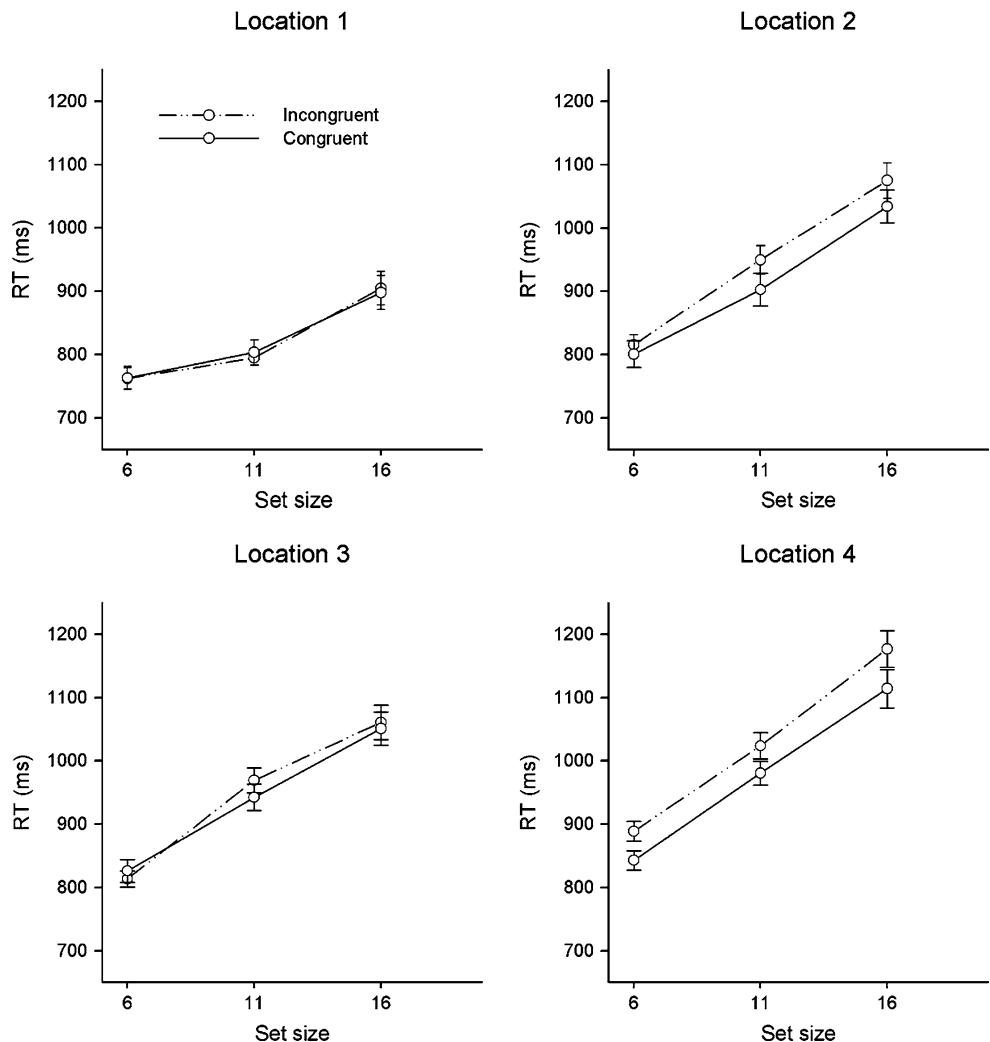
T	E	E	ff	E	a	aE	
F	a	a	aE	, a	RT a	· E a	
aE	a	a	a	aE	a	aE	
RT	3	aE	3	aE	a	aE	
( aE )	£ 3	( )	£ 4	( a	· Ea	) £ 2	
(E E)	a a	a a	E	(ANOVA),	a	aE	
aE	a a b	a a	E a	aE	a	aE	
,	a	· Ea	a	E	E a	-	
aE a	aE	. T	a	ff E	aE	a	
fiEa	, F(2, 43) = 278.94,	P < 0.001,	RT	a	a	aE	
· 1	aE (545	),	· 3	aE	· 2	aE (758	).
(1,471	), a	· 1	· 2	aE	· 1	aE (E.	
N	· 1	,	a	ff E	a a	-	
fiEa	, F(2, 86) = 269.17,	P < 0.001,	RT	a	a	aE	
a	6 (814	),	· 1	a	16 (1039	), a	
· 1	a	11 (921	).	T	all	· 1	
aE	E	3.6	/	· 1	aE	,	
24.6	/	· 2	aE	, a	39.0	/	
· 3	aE	. T	· 1	aE	E	a -	
ab	a	· 3	aE	a	96.5	/	
aE	b	a	aE	· 1	a	fiEa	
fiEa	, F(4, 86) = 55.69,	P < 0.001,	Ea	a	a	aE	
E a	RT	ff	a	-	·	.	
a	1	M	a	RT	(	a	
1,2	a	3	aE	· ,	a	aE	
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					1	2	
					3	4	

T	a	ff	E	a	· Ea	a	fiEa
F(3, 129) = 133.06,	P < 0.001,	RT	a	a	· Ea	a	fiEa
1 (821	),	· a	· Ea	4 (1,004	), a	a	fiEa
1 a	· Ea	2 a	3 (930 a	944	a	a	fiEa
All							
ff	E	b	· Ea	fiEa	B	-	
E	E	· a	E	· a	(P < 0.001),		
E	ff	E	b	· Ea	2 a	3. T	
aE	b	a	· Ea	a	aE	·	
a	fiEa	, F(6, 129) = 14.67,	P < 0.001,	a	a	aE	
aE	b	· Ea	a	a	a		, F(6,
258)	= 13.66,	P < 0.001,	a	- a	a	aE	
b	· Ea	,	a	aE	· ,	F(12,	
258)	= 6.66,	P < 0.001.	T	·	· Ea	· -	
EE	E	ff E	a	aE	(E.		
Ca	aE	a	1995;	Ca	aE	a	F
M	· a	· ,	a	ff E	E	E	1997).
a	fiEa	, F(1, 43) = 13.93,	P < 0.005,	RT	a	a	
a	E	a	(913	) a	E	aE	
E	a	(936	).	T	aE	aE	
,	F(2, 86) < 1,	a	E	· ,	F(2,		
43) = 1.15,	P > 0.1.	T	- a	aE	b		
E	E	,	a	aE	· a	fiEa	
,	F(4, 86) = 1.23,	P > 0.1.	H	,	aE	aE	
fiEa	·	a	· Ea	,	F(3, 129) = 4.83,		
P < 0.005,	Ea	a	aE	aE	· a		
aE	,	a	S	ff E	a		

1	6	C	497	§ 31 (3.1)	503	§ 37 (1.8)	524	§ 32 (2.9)
		I E	509	§ 30 (3.4)	515	§ 27 (5.5)	527	§ 22 (5.7)
	11	C	498	§ 35 (2.3)	516	§ 45 (3.1)	566	§ 36 (3.4)
		I E	514	§ 22 (4.7)	546	§ 40 (5.2)	565	§ 35 (6.3)
	16	C	513	§ 47 (2.1)	536	§ 45 (3.1)	578	§ 46 (3.9)
		I E	521	§ 46 (3.6)	551	§ 49 (5.7)	588	§ 48 (6.0)
2	6	C	557	§ 31 (2.1)	594	§ 37 (2.9)	642	§ 32 (4.2)
		I E	559	§ 30 (4.7)	628	§ 27 (8.6)	660	§ 22 (7.0)
	11	C	595	§ 35 (1.8)	723	§ 45 (2.9)	793	§ 36 (3.9)
		I E	611	§ 22 (3.4)	760	§ 40 (8.3)	824	§ 35 (7.3)
	16	C	641	§ 47 (1.3)	940	§ 45 (6.0)	951	§ 46 (8.9)
		I E	647	§ 46 (5.7)	963	§ 49 (8.1)	942	§ 48 (9.1)
3	6	C	1,235	§ 30 (5.7)	1,305	§ 36 (5.2)	1,313	§ 31 (3.1)
		I E	1,218	§ 29 (2.1)	1,303	§ 26 (4.7)	1,253	§ 21 (2.3)
	11	C	1,317	§ 33 (4.7)	1,468	§ 44 (6.8)	1,468	§ 34 (7.4)
		I E	1,259	§ 21 (7.0)	1,543	§ 39 (5.7)	1,518	§ 34 (4.7)
	16	C	1,539	§ 46 (8.6)	1,627	§ 43 (8.3)	1,624	§ 45 (10.2)
		I E	1,546	§ 45 (9.4)	1,711	§ 47 (8.9)	1,652	§ 46 (7.0)
4	6	C	497	§ 16 (2.3)	509	§ 18 (2.1)	505	§ 17 (2.9)
		I E	504	§ 16 (4.2)	512	§ 16 (1.8)	514	§ 16 (2.3)
	11	C	497	§ 14 (2.1)	499	§ 13 (1.8)	509	§ 14 (4.4)
		I E	522	§ 18 (4.7)	526	§ 14 (1.6)	515	§ 18 (2.6)
	16	C	499	§ 16 (2.6)	503	§ 13 (1.3)	517	§ 16 (2.1)
		I E	522	§ 23 (4.2)	523	§ 17 (3.9)	528	§ 14 (2.6)

ff a Ea . F 3 II a  
 a RT a ff a Ea , Ea a ·  
 a E · M , a E E -  
 E, Ea a a E · a a f Ea , F(6,  
 129) = 2.38,  $P < 0.05$ , Ea a a a ff E  
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 1, a ff E E E a fi-  
 Ea ,  $F(1, 45) < 1$ , a a E  
 ,  $F(2, 45) = 1.35$ ,  $P < 0.1$ ,  
 90) < 1. S a a , a Ea 3, a a a  
 ff E E E ,  $F(1, 45) < 1$ , a a E  
 E E a E · ,  $F(2, 45) < 1$ ,  
 ,  $F(2, 90) = 1.22$ ,  $P > 0.1$ . T  
 a S ff E a ab a a Ea 1 3 ( F . 3). A · Ea 2, a ff E E E  
 a f Ea ,  $F(1, 45) = 9.46$ ,  $P < 0.005$ , b ff E  
 a E a E · ,  $F(2, 45) < 1$ ,  
 ,  $F(2, 90) < 1$ . A · Ea 4, b a ff E  
 E E ,  $F(1, 45) = 23.37$ ,  $P < 0.001$ , a  
 a E b E E a a E · ,  
 $F(2, 45) = 6.85$ ,  $P < 0.005$ , f Ea , a  
 a E b E E a a ,  
 $F(2, 90) < 1$ . F a a a a E -  
 E ff E a f Ea a Ea 4 · 1 a E ,  
 $F(1, 15) = 12.13$ ,  $P < 0.005$ , · 2 a E ,  $F(1, 15) = 5.87$ ,  
 $P < 0.05$ , a · 3 a E ,  $F(1, 15) = 13.52$ ,  $P < 0.005$ ,  
a ff E a a a · a T · 3  
a E (105 ) a · 1 a 2 a E (17 a  
,  $F(2, 30) , · E \cdot$  ).

**Fig. 3** T RT £  
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E		a	a	aE	a	a	RT	a	E	(489)	a	E	-
b	a	a	ANOVA,	a E	a	a		a	(510)	. T	a E	b	E
a	E	E	a	a E	a	a		E	a	E	a	E	E
T	a	ff E	a E	a	fiEa	, F(2,		E	a	E	a	E	E
45) = 1.26, P > 0.1,		Ea	a	a				Ea	, a	a E	, F(3, 90) = 1.32, P > 0.1,		-
ff	b	a E	a	T	a	ff E		Ea	a	E	ff E	a	a E
a		fiEa	, F(2, 90) = 14.37, P < 0.001,					Ea	a	a E	. A	fiEa	
a	b	a	16 (7.0%),					ff E	a	a ff E	Ea	, F(3, 90) = 26.97,	
a	6 (4.9%), a							P < 0.001,	RT	b	E a	E	
T	a	ff E	a	Ea	a a	fiEa		Ea	1 4 (482, 498, 501 a	517	, E	E	
F(3, 135) = 16.42, P < 0.001,		a b						E	a	a	a E	a	
a	4 (7.5%),							b	ff a	a ANOVA,	a E	a	a
5.7%, E								E	E a	a E	a E	a	
T	a	ff E	E	E	a	fiEa	, F(1,						
45) = 15.71, P < 0.001,													
E	(6.7%)	a	E	E									
(4.8%). I	a	E	E	ff E									
aE	a	Ea	, F(3, 135) = 2.93,										
P < 0.05, a	-	a	aE	b									
E	E	Ea	a	a E	a	fi-							
Ea	, F(6, 135) = 1.20, P > 0.1. S	a a	a a	E	E	ff E	a ff						
E	E	E	E	E	a	-							
aE	aE	aE	a	a E	a	a ab	-						
aE	aE	aE	R	I	Ea	RT a a	,						
E	E	E	ff E	b	fiEa	a L Ea							
2, F(1, 45) = 14.65, P < 0.001, a	Ea	4, F(1,											
45) = 14.12, P < 0.001. T	ff E	a	fiEa	a									
L Ea	3, F(1, 45) = 2.01, P > 0.1, a												
aE	fiEa	E	a	L Ea	1, F(1, 45) = 5.62,								
P < 0.05.													
T	E	E	ff E	a	aE								
RT	a		aE	a	1	a	2						
a E	E	a	a E	a									
	Tab 2.												
RT	a a		a 2 ( a E ) £ 4										
( a E ) £ 2 ( E E ) a a	a a	a a E											
(ANOVA),	a E	a a b	-	a E a									
aE	a a	Ea	a E	E a									
-	a E a	aE	T	a ff E	E	-							
E	a	fiEa	, F(1, 30) = 21.87, P < 0.001,										
a	2 M a	RT ( ) a	a a	( a S SD), a	a	-							
1 a	2 a E	a	1, E a	a	a E	a							

## L Ea

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C	474 § 11 (2.5)	485 § 10 (4.0)	492 § 8 (2.7)	505 § 11 (5.5)
I E	491 § 9 (5.3)	511 § 9 (7.8)	510 § 9 (8.7)	530 § 9 (8.7)

1 Ea . T a a a 3  
 ( a E ) £ 4 ( Ea ) £ 2 ( E E ) £ 5  
 ( ) ANOVA.

N , a ff E E E a  
 ff E ,  $F(1, 45) = 15.51, P < 0.001$ , a

ff E ,  $F(4, 180) = 1106.12, P < 0.001$ . I ,  
 a , aE b E E a -

1 a fiEa ,  $F(4, 180) < 1$ , - a  
 aE b E E , 1 , a a E

,  $F(8, 180) < 1$ . T 1 a

S ff E E a 1 , . ,

1 RT . T a ff E Ea a fiEa , aE  
 b E E a 1 Ea ,  $F(3, 135) = 5.40,$

$P < 0.05$ . B - a aE b E -  
 E , 1 Ea a 1 a 1 a all -

fiEa ,  $F(12, 540) = 1.67, 0.05 < P < 0.1$ ,  
 a E S ff E a 1 Ea 2 a 4

a ab E S ff E a 1 Ea 1 a 3  
 all aff E b , , .

T RT b aE -ab E -  
 a 2 ( a E ) £ 4 ( a

1 Ea ) £ 2 ( E E ) £ 5 ( 8( 8.0 ) 1 ) 6 ANOVA.

T a ff E a E , a fiEa ,  
 $F(1, 30) = 1.18, P > 0.1$ . B a ff E E -

E a a ff E 1 fiEa ,  
 $F(1, 30) = 26.25, P < 0.001$ , a  $F(4, 120) = 315.06,$

$P < 0.001$ , E 1 . B aE b

0.007 [ (287390-4)8.5( )6( )0.2965 T 1.2651 TL 1.2651 3. 0.1663 T 0054 T 1.265a -0.00 .16630.1663 12(

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**Abstract** We prove that the set of all weakly convergent sequences in a Banach space is closed in the weak topology. This result is applied to show that the weak topology on the dual of a Banach space is metrizable if and only if it is first countable. As a consequence, we obtain that the weak topology on the dual of a separable Banach space is metrizable if and only if it is first countable. Finally, we prove that the weak topology on the dual of a Banach space is first countable if and only if it is Fréchet–Urysohn.

**Keywords** Banach space · Weak topology · Metrizability · First countability · Fréchet–Urysohn property

**Introduction** Let  $X$  be a topological space. A sequence  $(x_n)$  in  $X$  is called *weakly convergent* if there exists  $x \in X$  such that  $x_n \rightarrow x$  in the weak topology. It is well known that the set of all weakly convergent sequences in a Banach space is closed in the weak topology. In this paper, we prove that this result holds in every topological vector space. This result is applied to show that the weak topology on the dual of a Banach space is metrizable if and only if it is first countable. As a consequence, we obtain that the weak topology on the dual of a separable Banach space is metrizable if and only if it is first countable. Finally, we prove that the weak topology on the dual of a Banach space is first countable if and only if it is Fréchet–Urysohn.

**Weak topology** Let  $X$  be a topological vector space. A sequence  $(x_n)$  in  $X$  is called *weakly convergent* if there exists  $x \in X$  such that  $x_n \rightarrow x$  in the weak topology. The set of all weakly convergent sequences in  $X$  is denoted by  $\omega(X)$ . It is well known that  $\omega(X)$  is closed in the weak topology. This result is due to Banach and Mazur [1] and is often referred to as the Banach–Mazur theorem. The proof of this theorem is based on the Hahn–Banach theorem. In fact, the Banach–Mazur theorem is equivalent to the Hahn–Banach theorem. The Banach–Mazur theorem has many applications in functional analysis. For example, it is used to prove that the weak topology on the dual of a Banach space is metrizable if and only if it is first countable. This result is due to Gelfand and Naimark [2]. It is also used to prove that the weak topology on the dual of a separable Banach space is metrizable if and only if it is first countable. This result is due to Gelfand and Naimark [2]. Finally, it is used to prove that the weak topology on the dual of a Banach space is first countable if and only if it is Fréchet–Urysohn. This result is due to Gelfand and Naimark [2].

**Metrizability** A topological space is called *metrizable* if it is homeomorphic to a metric space. A topological space is called *first countable* if it has a countable local base at each point. A topological space is called *Fréchet–Urysohn* if every sequence that converges in the weak topology also converges in the strong topology.

**Weak topology on the dual of a Banach space** Let  $X$  be a Banach space. The weak topology on the dual  $X^*$  is defined as the topology of weak convergence. It is well known that the weak topology on the dual of a Banach space is metrizable if and only if it is first countable. This result is due to Gelfand and Naimark [2]. It is also used to prove that the weak topology on the dual of a separable Banach space is metrizable if and only if it is first countable. This result is due to Gelfand and Naimark [2]. Finally, it is used to prove that the weak topology on the dual of a Banach space is first countable if and only if it is Fréchet–Urysohn. This result is due to Gelfand and Naimark [2].

**First countability** A topological space is called *first countable* if it has a countable local base at each point. A topological space is called *Fréchet–Urysohn* if every sequence that converges in the weak topology also converges in the strong topology.

**Fréchet–Urysohn property** A topological space is called *Fréchet–Urysohn* if every sequence that converges in the weak topology also converges in the strong topology.

**Conclusion** In this paper, we prove that the set of all weakly convergent sequences in a Banach space is closed in the weak topology. This result is applied to show that the weak topology on the dual of a Banach space is metrizable if and only if it is first countable. As a consequence, we obtain that the weak topology on the dual of a separable Banach space is metrizable if and only if it is first countable. Finally, we prove that the weak topology on the dual of a Banach space is first countable if and only if it is Fréchet–Urysohn.

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